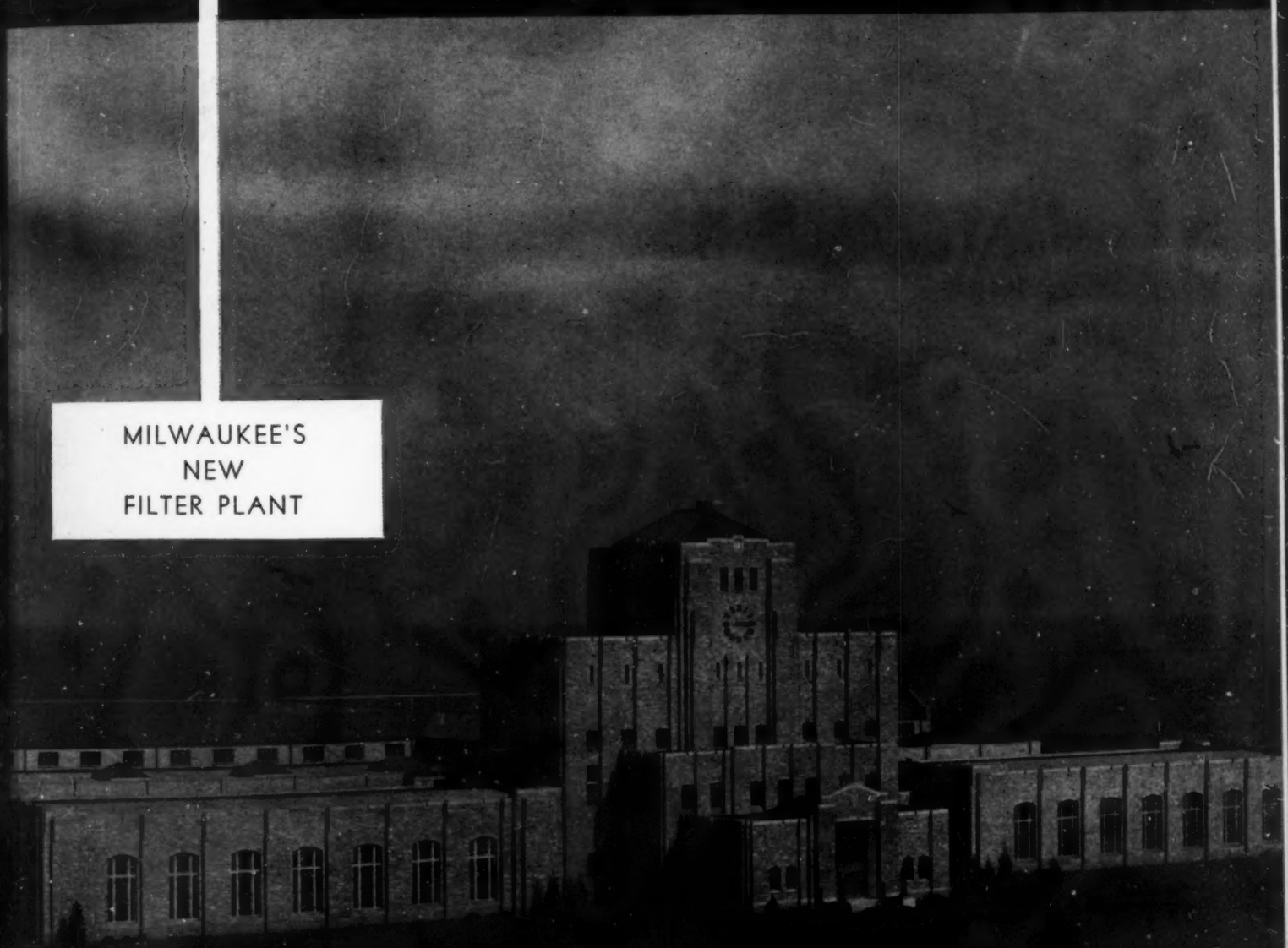
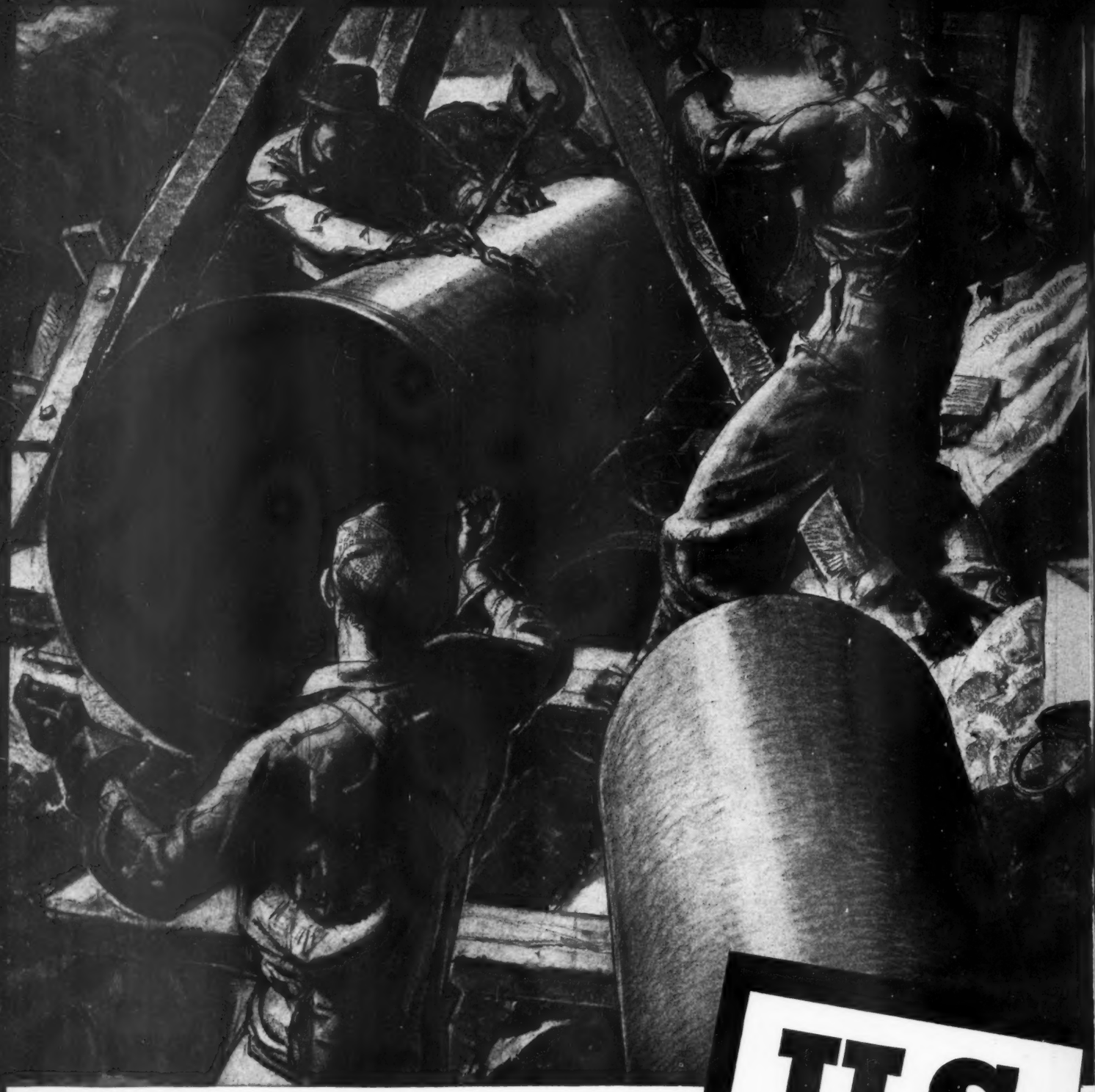
WATER WORKS & SEWERAGE





Copyright, 1940, U. S. Pipe & Foundry Co.

CAST IRON pressure pipe for underground service has a useful life of one hundred years. This is virtually an engineering axiom applying to *all* cast iron pressure pipe since all of it is made to specifications. But specification products can have plus-values, as in the case of Super-de Lavaud *chill-free* centrifugally cast pipe. This pipe, made by a special process, combines extraordinary impact-resistance with great strength and ductility.

U.S. cast iron PIPE

Centrifugally or Pit Cast for water works, gas, sewerage, drainage and industrial services.

U. S. PIPE & FOUNDRY CO.
General Offices, Burlington, N. J.

Plants and Sales Offices throughout the U. S. A.

Each municipality shown on this map has Clark-Sundh Electric Control apparatus in its Water Works and/or Sewage Treatment Plant. ● This is not only assurance that these communities are adequately provided with water and/or with waste disposal . . . it is a tribute to the efficacy of Clark-Sundh Electrical Control.

OFFICES IN PRINCIPAL CITIES

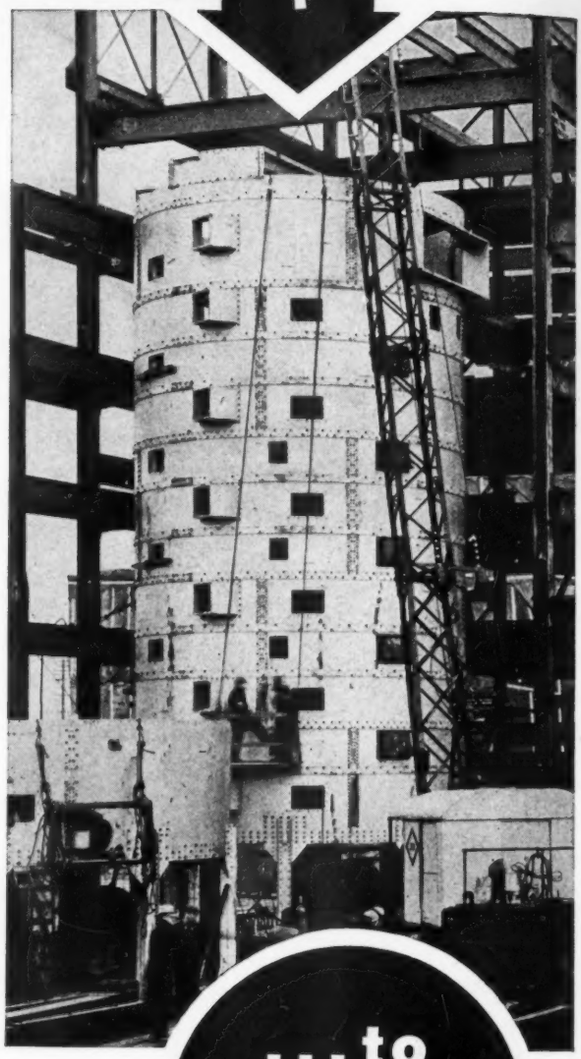
THE CLARK CONTROLLER CO.

1146 EAST 152ND ST. CLEVELAND, OHIO

WATER WORKS & SEWERAGE, April, 1940. Volume 87. Number 4. Published monthly at 330 South Wells Street; Chicago, Ill., by the Gillette Publishing Company. Per copy, 50c. Subscription rate, United States and Canada, $2.00 per year; Foreign, $3.00 per year. Copyright, 1940. Entered as Second Class Matter, June 2, 1931, at the Post Office at Chicago, Ill., under Act of March 3, 1879.

From Offensive Sewage Sludge...

Annually more than a million tons of sewage sludge drop from one NICHOLS HERRESHOFF HEARTH to another, discharging from the bottom hearth as sterile ash



...to Sterile Ash

Thirty-four United States communities are now disposing of their dangerous and offensive sewage solids in this sanitary manner—without smoke or offensive odors—and at a remarkably low cost per ton of sludge incinerated.

Units now operating range in size from 4 tons to 1400 tons daily capacity.

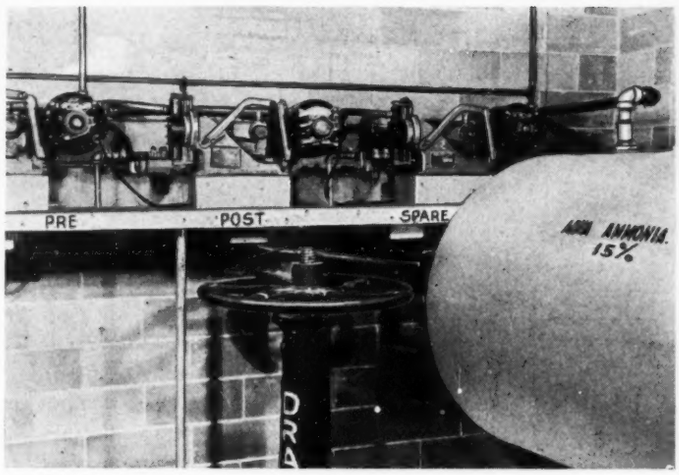
Any community interested in the sanitary disposal of municipal solid wastes—including sewage sludge, screenings, grit, garbage or rubbish should write "Incineration Headquarters" for information and data.

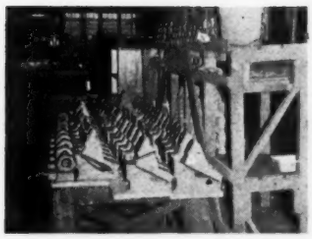
NICHOLS

ENGINEERING & NERCO RESEARCH CORP.

60 WALL TOWER **NEW YORK, N. Y.**

News from % Chemical Feeder Headquarters





Above: "Midgets" are produced in quantity, stocked for shipment.

Left: Amm-O-Feeders at Dalecarlia Filter, Washington, D. C.

"We are saving $105 per month by feeding Aqua Ammonia with Amm-O-Feeder, instead of using Anhydrous" —thus writes C. J. Lauter, Chemical Engineer, Dalecarlia Filtration Plant, Washington, D. C., who has proof in actual figures from that plant (which formerly used anhydrous ammonia). At McMillan Filter, just starting the use of aqua, Mr. Lauter expects a similar saving. ***You should investigate***—the chemical costs less, the feeder costs less—there is no limit to the size of the plant which can save by using aqua, in fact, the larger the plant the larger the savings.

XSD CHLORINATION

(i.e., excess and de-chlorination) brings the-story-of-the-month in the form of a letter from Ottumwa Water Works, Iowa. This community takes its water supply from the Des Moines River, about 125 miles below the city of Des Moines which dumps its raw sewage into the river. Extreme drought reduced the river level to a record-breaking low flow, a cold spell froze the river over solidly—the taste and odor at Ottumwa were terriffic! After trying several methods, the problem was finally solved by superchlorination, followed by dechlorination using a %Proportioneers' Midget feeding sodium bisulphite.

Floods bring problems right down %Proportioneers' Alley. Boxed units stand ready in our shipping department waiting for your emergency wire orders. Just another advantage of quantity production methods, illustrated. How about ordering an emergency unit to have on hand just in case—

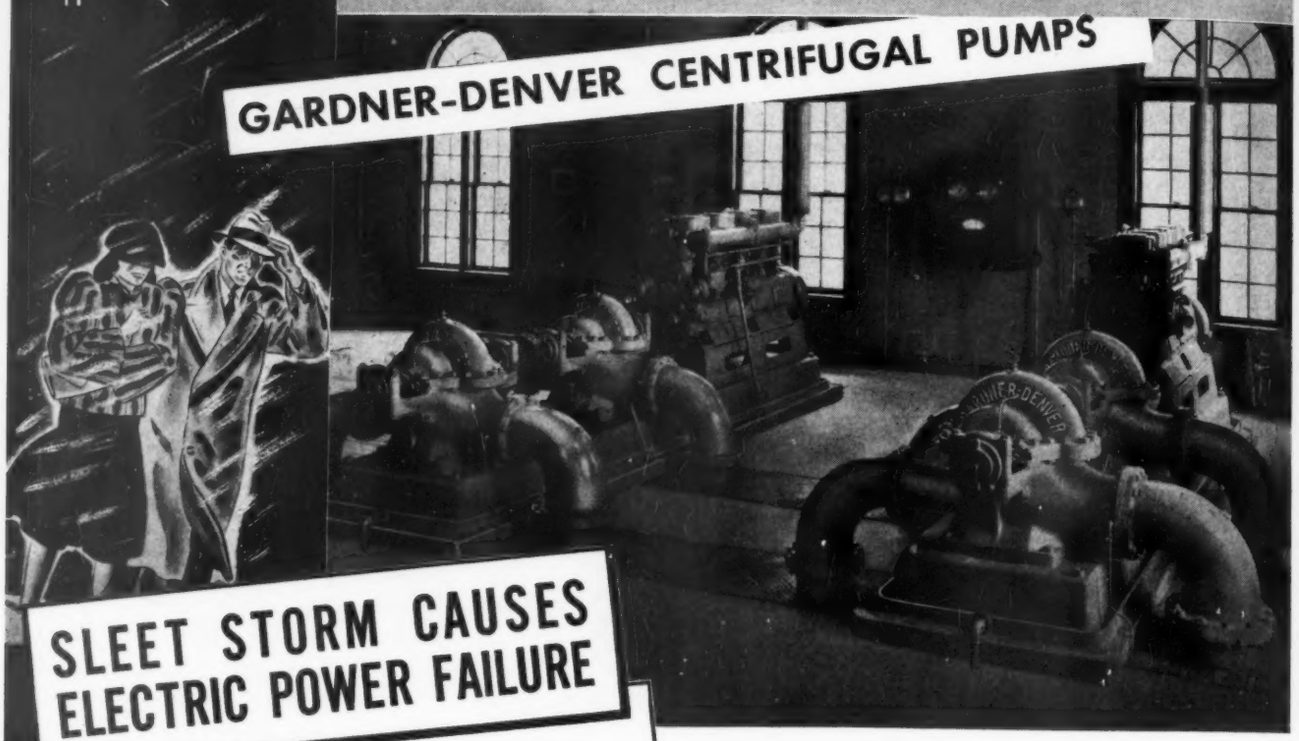
Visit our "Fun House" at Kansas City — %Proportioneers will be on hand in full force—it's Booth 43.

% PROPORTIONEERS %

9 N. Codding Street **Providence, R. I.**

"SPOT-LIGHTED" FOR WATERWORKS SERVICE BECAUSE OF SUPERIOR PERFORMANCE

GARDNER-DENVER CENTRIFUGAL PUMPS



SLEET STORM CAUSES ELECTRIC POWER FAILURE

Gardner-Denver Standby Pumps Deliver 1,000,000 Gallons Per Day OVER Their Rated Capacity!

The Gardner-Denver pumps illustrated are installed as standby and emergency units in a western waterworks serving a city of 40,000 population. The reserve power of the pumps was put to a severe test during a sleet storm which cut off all the city's electrical power. These pumps were immediately put into operation to answer the water requirements of 40,000 people. The performance of the Gardner-Denver pumps exceeded the rated capacity: instead of pumping their rated capacity of 6,000,000 gallons per day, they actually pumped 7,000,000 gallons per day! The installation consists of two complete units, each containing two Gardner-Denver 8″ type D Horizontally Split-Case Centrifugal Pumps connected in series, and direct-connected to 8-cylinder Sterling gasoline engines. The pumps are operated at 1250 r. p. m. and are pumping against a 250-ft. head.

Although the photograph shows gasoline engine drive, Gardner-Denver pumps are adaptable to any type.

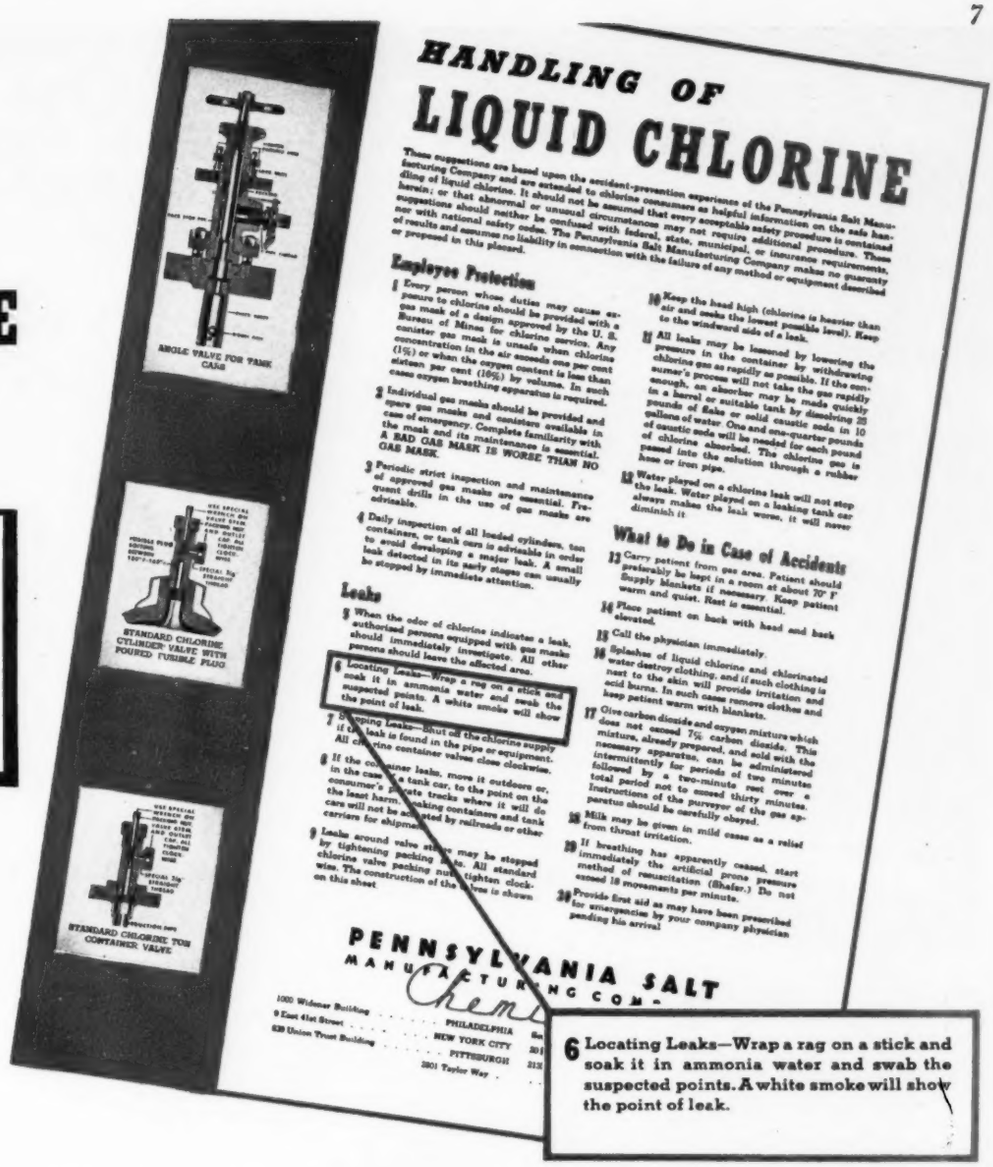
EMERGENCIES throw the spotlight on the superior performance of Gardner-Denver Centrifugal Pumps in waterworks service—but the greatest testimonial to the higher efficiency and lower power cost of these pumps is the day-by-day service they are rendering in municipal and industrial installations throughout the country. Designed and built without compromise . . . embodying superior hydraulic and mechanical features . . . Gardner-Denver pumps are establishing remarkable service records . . . saving thousands of dollars for their owners. If your city is interested in substantially lowering the cost of water pumped, you should have full information about Gardner-Denver Centrifugals. We shall be glad to send you complete details . . . there is no obligation, of course. Gardner-Denver Company, Quincy, Illinois.

GARDNER-DENVER

SINCE 1859

FOR CHLORINE USERS

• Valuable wall placard on "Handling of Liquid Chlorine"


ANGLE VALVE FOR TANK CARS
STANDARD CHLORINE CYLINDER VALVE WITH FUSIBLE PLUG
STANDARD CHLORINE TON CONTAINER VALVE
HANDLING OF
LIQUID CHLORINE
Employee Protection
Leaks
What to Do in Case of Accidents
6 Locating Leaks—Wrap a rag on a stick and soak it in ammonia water and swab the suspected points. A white smoke will show the point of leak.

Pennsylvania Salt Manufacturing Company has just published, in durable wall placard form, 20 outstanding suggestions on the handling of liquid chlorine. These are based on the long and extensive experience of this Company with every phase of liquid chlorine handling and usage, and embody safety recommendations that are readily understood and easily followed.

The placard is handsomely printed, and illustrated in color, and is strongly backed with canvas. It is free to chlorine users upon request. It will promote safety in your plant.

A new purifying process developed by Pennsylvania Salt Manufacturing Company produces a liquid chlorine which reduces chlorinator irregularities to a minimum. As a further safeguard, an improved analytical method has been developed for evaluating liquid chlorine as to such impurities. That is why you can rely so confidently on this product.

All containers in which this liquid chlorine reaches you are carefully cleaned and rigidly inspected before each shipment, and valves are always reconditioned and repacked. They look the part, for the handsome appearance of all containers is maintained with equal care.

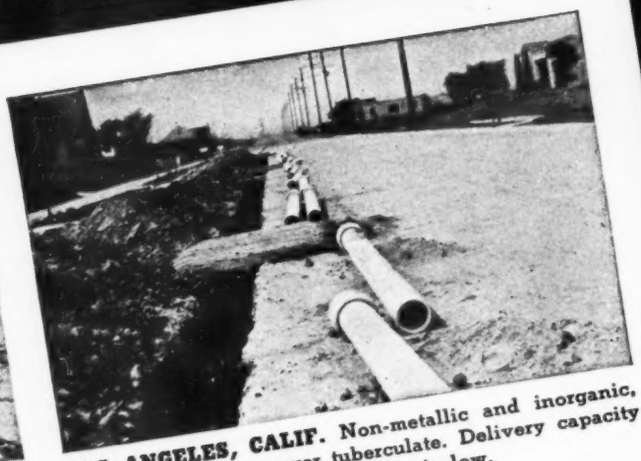
If you are a user of liquid chlorine, be sure to write immediately for your free copy of the valuable wall placard. Pennsylvania Salt Manufacturing Company, Widener Building, Philadelphia, Pa.—New York • Chicago • St. Louis • Pittsburgh • Tacoma • Wyandotte.

PENNSYLVANIA SALT
MANUFACTURING COMPANY
Chemicals

• Make your plans to attend the 60th Annual Meeting of the AWWA, Kansas City, Mo.

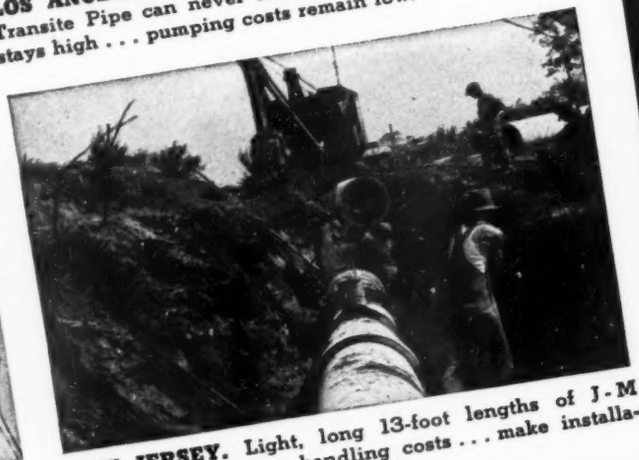
You Can Reduce Your

W. MANSFIELD, OHIO. Made of asbestos and cement, Transite Pipe offers exceptional resistance to all forms of corrosion and is immune to electrolysis.



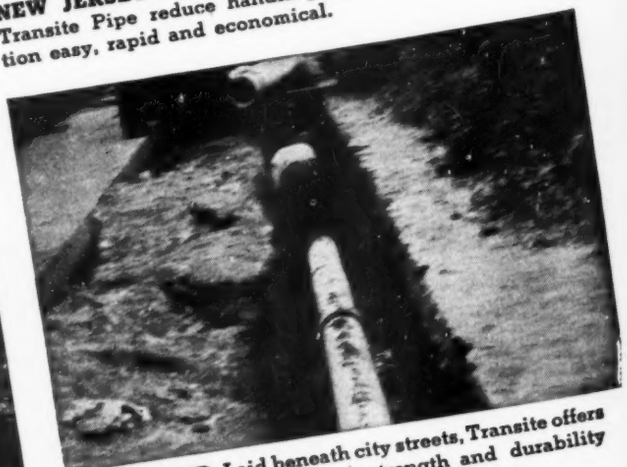
LOS ANGELES, CALIF. Non-metallic and inorganic, Transite Pipe can never tuberculate. Delivery capacity stays high . . . pumping costs remain low.

SHARON, MASS. Simplex Couplings assure joints that *stay* tight. Furthermore, their ease of assembly speeds up installation . . . keeps costs low.



NEW JERSEY. Light, long 13-foot lengths of J-M Transite Pipe reduce handling costs . . . make installation easy, rapid and economical.

YPSILANTI, MICH. No large bell holes are needed with Transite. Trenches can be held to narrow, economical widths . . . damage to pavements is minimized.



BRAZIL, IND. Laid beneath city streets, Transite offers every advantage of uniform strength and durability necessary for long life and low maintenance.

Water-Line Costs . . .

Transite Pipe has helped hundreds of municipalities cut water-carrying costs—here's what it can do for you

Cut Your Installation Costs. Transite Pipe's long, light lengths are easily handled by installation crews. Flexible Simplex Couplings make assembly so easy that work goes fast even when wet trenches are encountered. And because no large bell holes are needed at joints, trenches can be narrower, more economical.

Cut Your Maintenance Costs. Made of asbestos and cement, Transite Pipe is unusually resistant to all forms of corrosion and immune to electrolysis. Its durability and uniform strength prevent damage by heavy earth loads or traffic stress.

Gives Higher Delivery Capacity. Transite's smooth interior surface offers an initial flow coefficient of C=140. Made of asbestos and cement, Transite can never tuberculate. Pumping expense is minimized. And joints stay tight . . . provide definite assurance against costly leakage.

Full details will show you other ways that Transite Pipe helps you cut costs and improve the efficiency of your water system. Send for brochure TR-11A. And for facts on J-M Transite Sewer Pipe, write for brochure TR-21A. Johns-Manville, 22 East 40th Street, New York, N. Y.

. . .

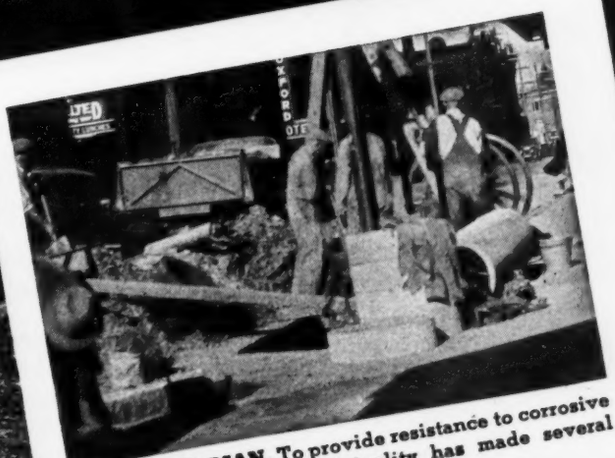
BE SURE TO ATTEND the 60th Annual Meeting of the American Water Works Association, Kansas City, Missouri, week of April 21st, 1940.

Johns-Manville

TRANSITE PIPE An Asbestos Product

The MODERN Material for Water and Sewer Lines

QUINCY, ILL. Transite is easily cut and sawed on the job. Service connections and fittings are cut in quickly and easily with ordinary tools.



WINNIPEG, MAN. To provide resistance to corrosive soil, this Canadian municipality has made several installations of J-M Transite Pipe.

Announcing

SURFACE WASH *wins* ACADEMY AWARD

IN THE MINDS OF WATER WORKS MEN

MR. C. E. PALMER—a practical water works man—inventor of the Palmer filter bed agitator.

The Palmer filter bed agitator is revolutionizing present methods for washing filters. The so-called surface wash system is truly the Academy award winner in water works practice this year.

For information and literature on how to

- lengthen filter runs—up to 200%
- eliminate mud balls—
- eliminate slime conditions
- reduce wash water—approx. 40%
- improve the taste of the water

ask for details at no obligation.

Simple to operate—Automatic—Inexpensive.

Visit the Activated Alum Corp. exhibit at Kansas City and see why Activated Alum and Activated Blackalum are *"America's Most Popular Water Works Coagulants."*

"Everybody Likes Activated Alum"

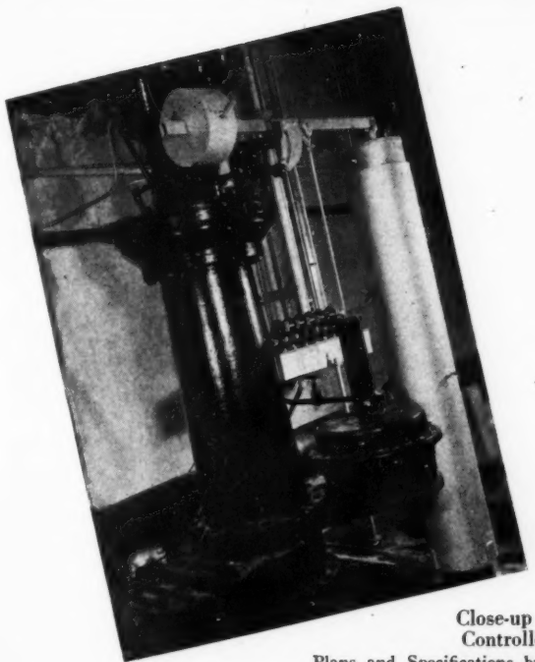
Exclusive International Sales Agent on Palmer Filter Bed Agitator — *Surface Wash Method of Washing Filters*

Activated Alum Corp.

CURTIS BAY, BALTIMORE, MARYLAND

LANSING SELECTS SIMPLEX

Operating Floor, Lansing, Michigan, Water Conditioning Plant.



Close-up Simplex No. 162 Vertical Controller and Master Control Station.

Plans and Specifications by Staff Engineers, Board of Water and Electric Light Commissioners. Otto E. Eckert, General Manager; Claude R. Erickson, Engineer; Alvord, Burdick and Howson, Engineering Consultants.

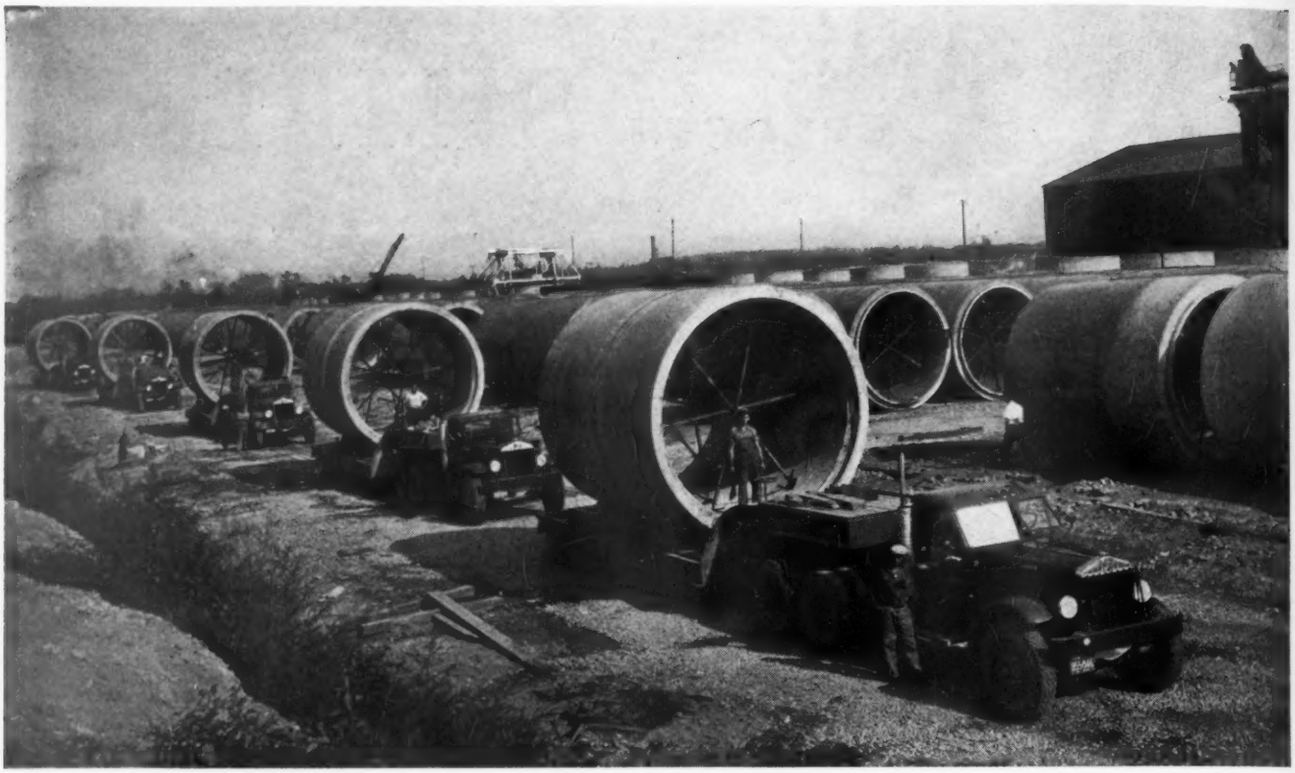
THE design of Lansing's Water Conditioning Plant presented many unique and peculiar problems in measuring and control. Studies by SIMPLEX ENGINEERS resulted in the development of a means of master and proportional control that insures automatic balancing of all flows, irrespective of changing supply or demand.

SIMPLEX is proud that in the selection of its Controllers, Gauges, Meters, Master Controls, and Sand Expansion Indicators by the Board of Water and Electric Light Commissioners, it was able to assist in the final construction of this most noteworthy addition to the country's Water Treatment Works.

LET SIMPLEX ENGINEERS ASSIST YOU IN SOLVING YOUR CONTROL AND METERING PROBLEMS

SIMPLEX VALVE & METER CO.

6743 UPLAND STREET • PHILADELPHIA, PA.



16 ft. lengths of 138" diameter Lock Joint pipe for the new Boston Pressure Aqueduct, loaded and ready for delivery. The manufacturing yard is in the background.

Lock Joint Reinforced Concrete Pressure Pipe Chosen For Long-Life Water Supply Lines

Bethlehem, Pa.
Birmingham, Ala.
Boston, Mass.
Denver, Colo.
Grand Rapids, Mich.
Harrisburg, Pa.
Newark, N. J.
New Rochelle, N. Y.
Portland, Me.
Tacoma, Wash.
West Palm Beach, Fla.
Whittier, Cal.

BY all standards the year 1939 was the greatest in the history of water works construction. Expenditures in all its branches greatly exceeded those of any previous year.

With this nation-wide demand for better and more abundant supplies of water, came also the demand for supply lines of enduring economy. To fulfill this demand pipe was required which would have and retain high carrying capacity as well as include those inherent qualities which permanently assure freedom from corrosion and tuberculation.

Admirably adapted to fulfill all of the requirements for a long-life, trouble-free pipe line is Lock Joint Reinforced Concrete Pressure Pipe. Its acceptance during 1939 stamped it as the outstanding material for permanent pipe line construction.

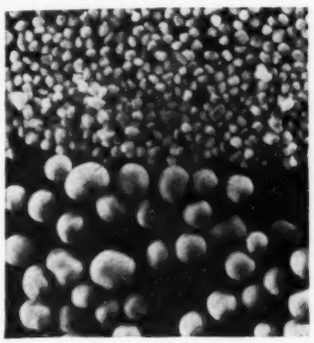
Indicative of the increased use of this pipe is the above list of cities in which installations were made during 1939, over 500,000 feet having been laid in major cities from Maine to California.

These far-sighted municipalities chose Lock Joint Pipe for their water supply lines because they knew that it would stand the test of time.

You'll want to learn more about the use of this pipe for your own installations either present or contemplated. Your letter will bring our prompt reply.

LOCK JOINT PIPE CO.
AMPERE, N. J.

SCALE in pipes, meters, valves, heater coils can be prevented with Calgon Threshold Treatment.



FILTER "PEARLS" formed in the sand filters of a softening plant. Calgon added to the influent water prevents this incrustation and cementation.

Calgon

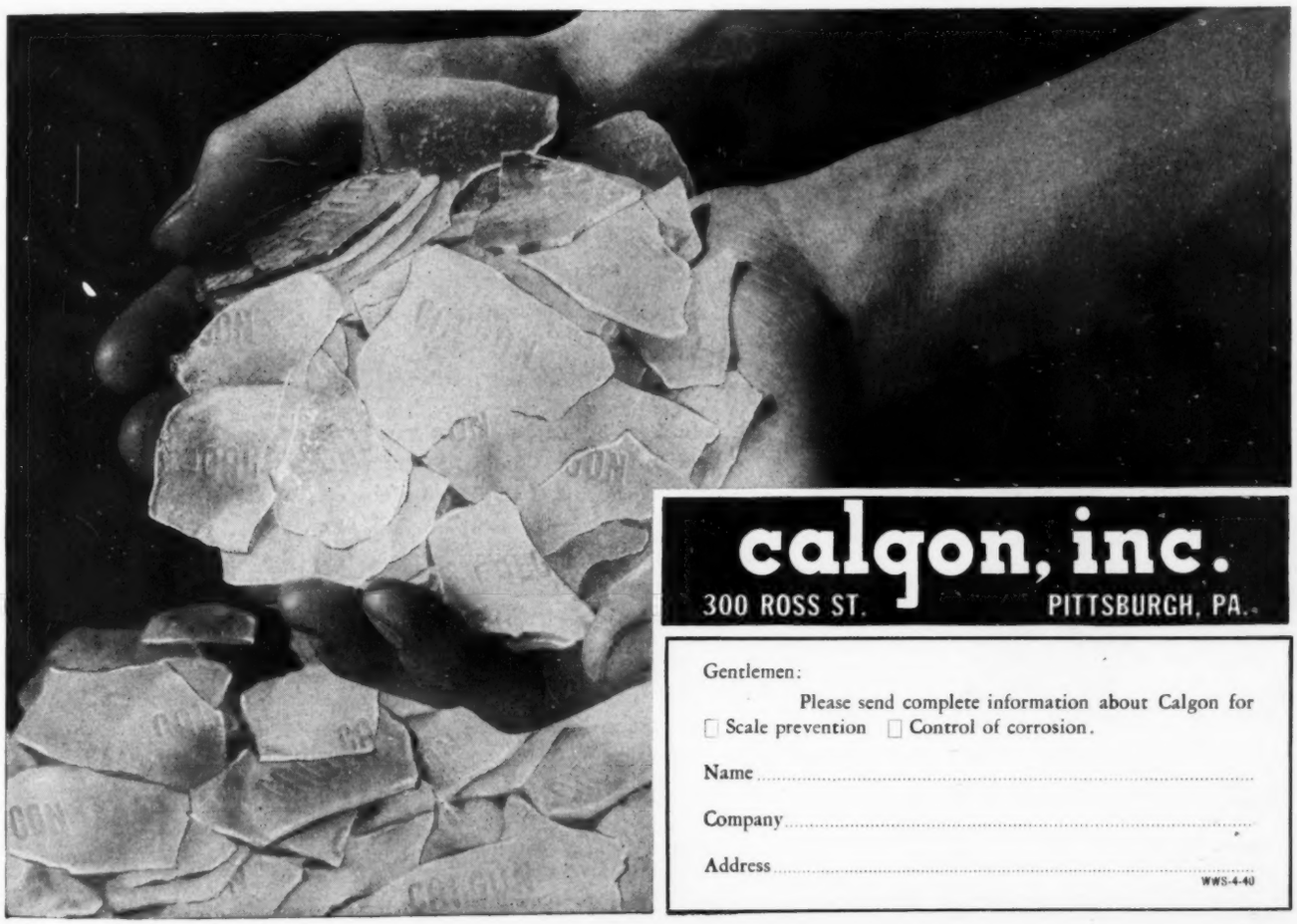
STOPS SCALE TROUBLES IN 80 CITY WATER SYSTEMS

CALGON Threshold Treatment was introduced to the municipal water field after its use in hundreds of industrial plants had proved its effectiveness. Immediately it was hailed by water works men as the most outstanding development in municipal water treatment in recent years. During the past 18 months more than 80 municipalities have adopted it as an effective method of preventing scale in filters, mains, valves, and hot-water heaters. Results in every case have proved that it is no longer necessary to put up with difficulties due to scale formation.

Calgon has the remarkable ability to stabilize water even at high pH values. Only 1 or 2 parts of Calgon per million will prevent the precipitation of calcium carbonate following softening or from a hard, unsoftened water. The small amount of Calgon required keeps the cost of Threshold Treatment extremely low.

Corrosion, too, can be controlled by Calgon Threshold Treatment. It may seem strange that Calgon is effective in the control of both scale and corrosion, but you may easily establish this fact. Calgon was developed by Hall Laboratories, Inc., well-known authorities on water conditioning. Send in the coupon for the complete scientific story behind this remarkable product.

"Calgon" is the registered trademark of Calgon, Inc. for its sodium metaphosphate products. Threshold Treatment is covered by U. S. Patent Re. 20,754.



calgon, inc.
300 ROSS ST. PITTSBURGH, PA.

Gentlemen:

Please send complete information about Calgon for
☐ Scale prevention ☐ Control of corrosion.

Name .....

Company .....

Address .....

WWS-4-40

NORIT

14 *and* 9

GUARANTEED VALUES

Buyers of *Powdered* Norit can count on a Phenol Value of 14 or better

Buyers of *Granular* Norit can count on a Phenol Number Not Less than 9

Each form of activated carbon has its advantages and its advocates in connection with odor and taste control of water. Powdered carbon can be applied easily and requires no changes in the plant setup. Granular carbon provides more complete utilization of the adsorption capacity; possibilities of regeneration in place; and simplicity of operation. The use of granular carbon is particularly advantageous in small plants. Sometimes it is advisable to combine the two in successive applications.

But regardless of which form is used, NORIT goes to the buyer with an odor and taste adsorbing capacity second to none. It's a pure wood product, made in Florida.

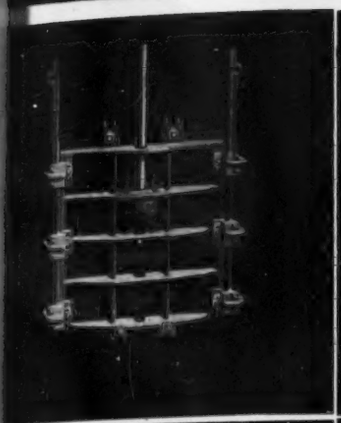
A rather detailed discussion of Water Treatment with Activated Carbon is given in this booklet. Send for a copy.

Sales Agents for

AMERICAN NORIT CO., Inc.
551 Fifth Avenue, New York
Plant: Jacksonville, Fla.

L. A. SALOMON & BRO.
216 Pearl St. New York, N. Y.

EQUIPMENT FOR EVERY NEED

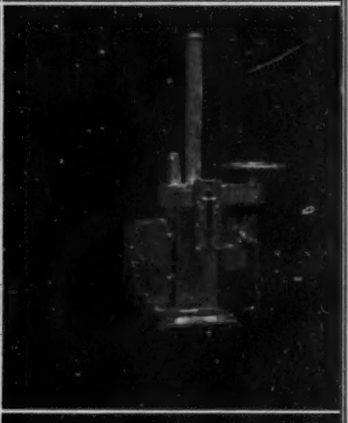


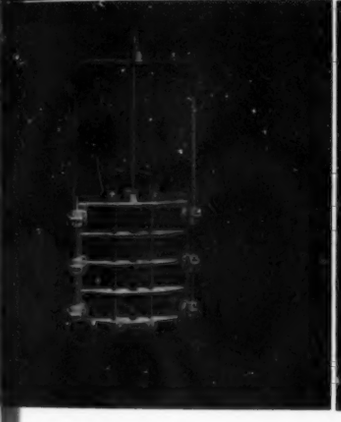
A-25400
Flap Valve

A-25601
Mud Valve

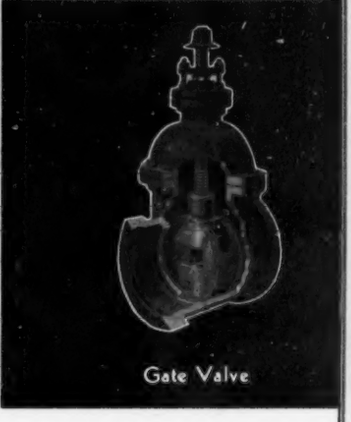
A-26006
Check Valve

Circular Sluice Gate
Non-Rising Stem





A-26426
Floor Stand



Gate Valve

No matter how large or how small your requirements may be, there probably is Mueller-Columbian Equipment available that will mean substantial savings. Most specifications can be met by Mueller Co. with their regular line of Sluice Gates, Gate Valves, Operating Controls (Manual, Hydraulic or Electric), Mud Valves, Flap Valves, Check Valves, etc. Unusual or special equipment can be furnished to exact specification and all Mueller-Columbian products have the benefit of specialized plant facilities and many years of engineering experience in all phases of water control projects.

Get in touch with Mueller-Columbian before you specify. It may result in unusual savings. Recommendations, specifications and estimates are cheerfully given.

The Mueller-Columbian A-300 Catalog is a combined catalog and handbook of information and should be in the hands of everyone interested in water controlling projects. We have a copy for you upon request.

Tear out and mail!

Mueller Co., Dept. WS 440
Chattanooga, Tenn.

Gentlemen:

Please send me a copy of your A-300 Catalog at once.

Name_____

Position_____

Address_____

City_____

They Started Something!

GREAT among the great men who "started something" in this world was Thomas Alva Edison. And probably the greatest of all the things he started was the incandescent lamp — an invention that turned night into day for millions of people and gave them new safeguards of vision. It gave the world a new industry, also, which is today one of the largest and most necessary — the electrical industry. Practically no single invention has such a deep and widespread effect upon the history of mankind.

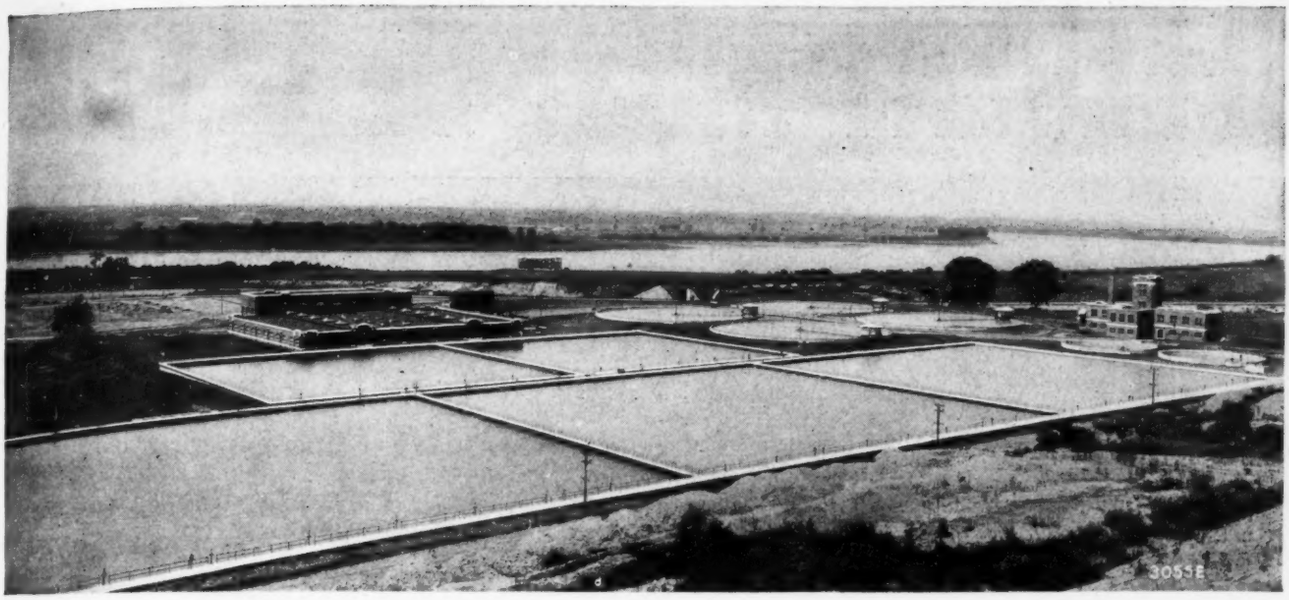
Edison's invention was successful because it met a vital need of humanity. The development of EBG engineers — the first commercial production of Liquid Chlorine in America — was successful for the same reason. Because this product was made available from a domestic source to users throughout the country many important advances have been made. Textile and paper bleaching has been placed on a more scientifically efficient basis. The bleaching of other products has also been greatly improved. Great savings in lives and improvements in standards of health have been made, too, because EBG pioneered in using Liquid Chlorine for water purification and the sterilization of sewage.

The first cylinder of Liquid Chlorine made by EBG in 1909.

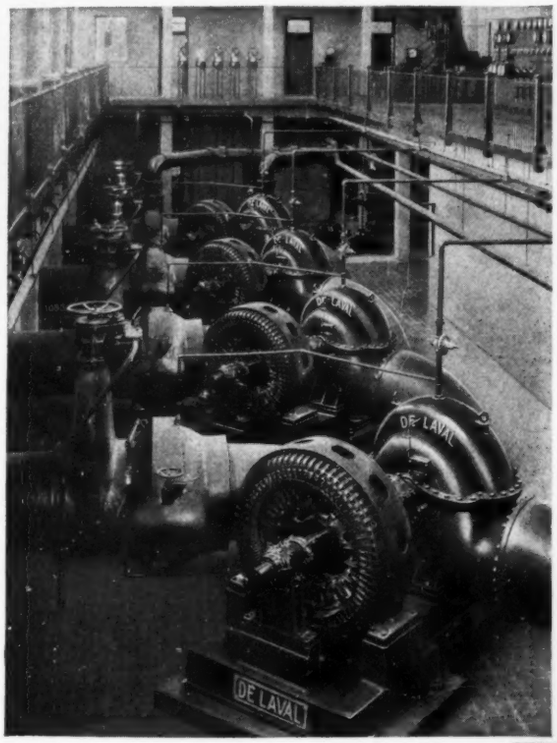
From the start EBG has always been a leader in the field of Liquid Chlorine. The special knowledge and experience gained by the company in its pioneering activity is *yours* when you use EBG Liquid Chlorine.

ELECTRO BLEACHING GAS COMPANY
Main Office: 60 East 42nd Street, New York, N. Y.
Plant: Niagara Falls, N. Y.

EBG Liquid Chlorine
FIRST IN THE COUNTRY



North Kansas City Plant, showing Low Lift Pumping Station, Preliminary Settling Tanks, Chemical Building, Mixing Tanks, Coagulating and Final Settling Basins, Filter Building and Secondary Pumping Station.



Secondary Lift Station, containing four De Laval pumps, three of which are of 35 m.g.d. and one of 20 m.g.d. capacity against 44 ft. head; also three wash water pumps and a four-stage high pressure pump.

The holding of the

1940 ANNUAL CONVENTION OF THE AMERICAN WATER WORKS ASSN.

in Kansas City, Mo., April 21 to 25,

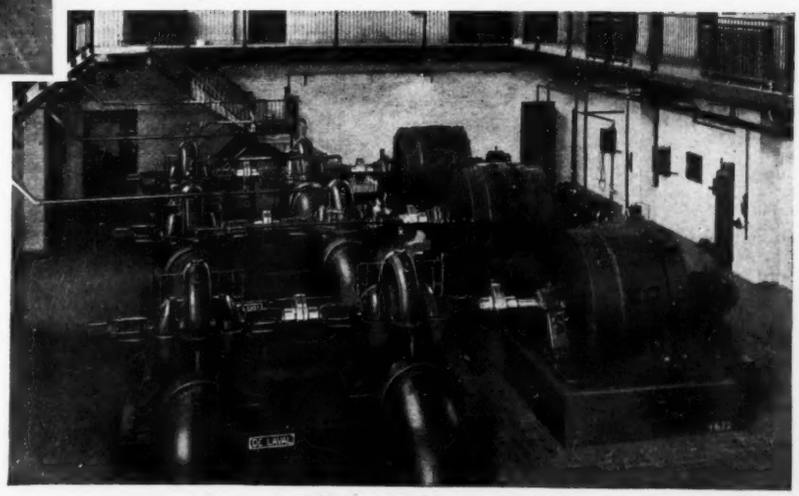
affords water works officials and engineers an opportunity to inspect that City's modernly designed and equipped Water Works System, which contains altogether some

24 DE LAVAL PUMPS

of an aggregate capacity of over 378 m.g.d.

Further particulars are given in Leaflet P-4100

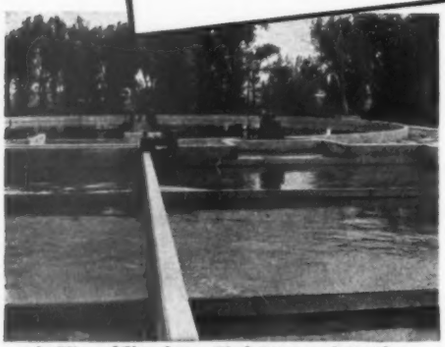
DE LAVAL STEAM TURBINE CO., TRENTON, N. J.



East Bottoms Station, containing three De Laval units, two of which are of 24 m.g.d. and one of 12 m.g.d. capacity. Impellers are kept on hand for changing the latter over to 24 m.g.d., when required.

EFFLUENT MUST BE CLEAR

...So Colorado Springs Disposal Plant Uses GENERAL CHEMICAL 'ALUM'



▲ *View of Flocculators, Flash Mixer and Clarifier.*

▲ *Note That Rocks Are Visible Showing Clarity of Effluent.*

*Designed by Burton Lowther, Consulting Engineer, Denver.

Clear, pure effluent is required at the Colorado Sewage Disposal Plant* because the effluent flows into a nearby river, the water of which is used during the summer months by farmers for crop irrigation. *For this reason, it is absolutely essential that the effluent be as clean as possible.*

Clarity and purity of effluent at Colorado Springs are accomplished by chemical precipitation using General Chemical Aluminum Sulfate and a small amount of lime for control of pH. Chlorine is used to reduce bacterial load.

General Chemical Aluminum Sulfate is used because:

1. It is simple to apply, clean and easy to handle.
2. Requires only simple, low cost equipment for application.
3. It is a year round coagulant.
4. Does not necessarily require other chemicals to complete the reaction and there is no complicated problem of properly proportioning two or more chemicals.
5. Can produce crystal clear, near zero turbidity effluent.
6. Precipitated sewage sludge digests easily and yields a high gas production.
7. Treated digested sludge dries quickly and without odor.
8. It is preferred and specified by a majority of important American municipalities.

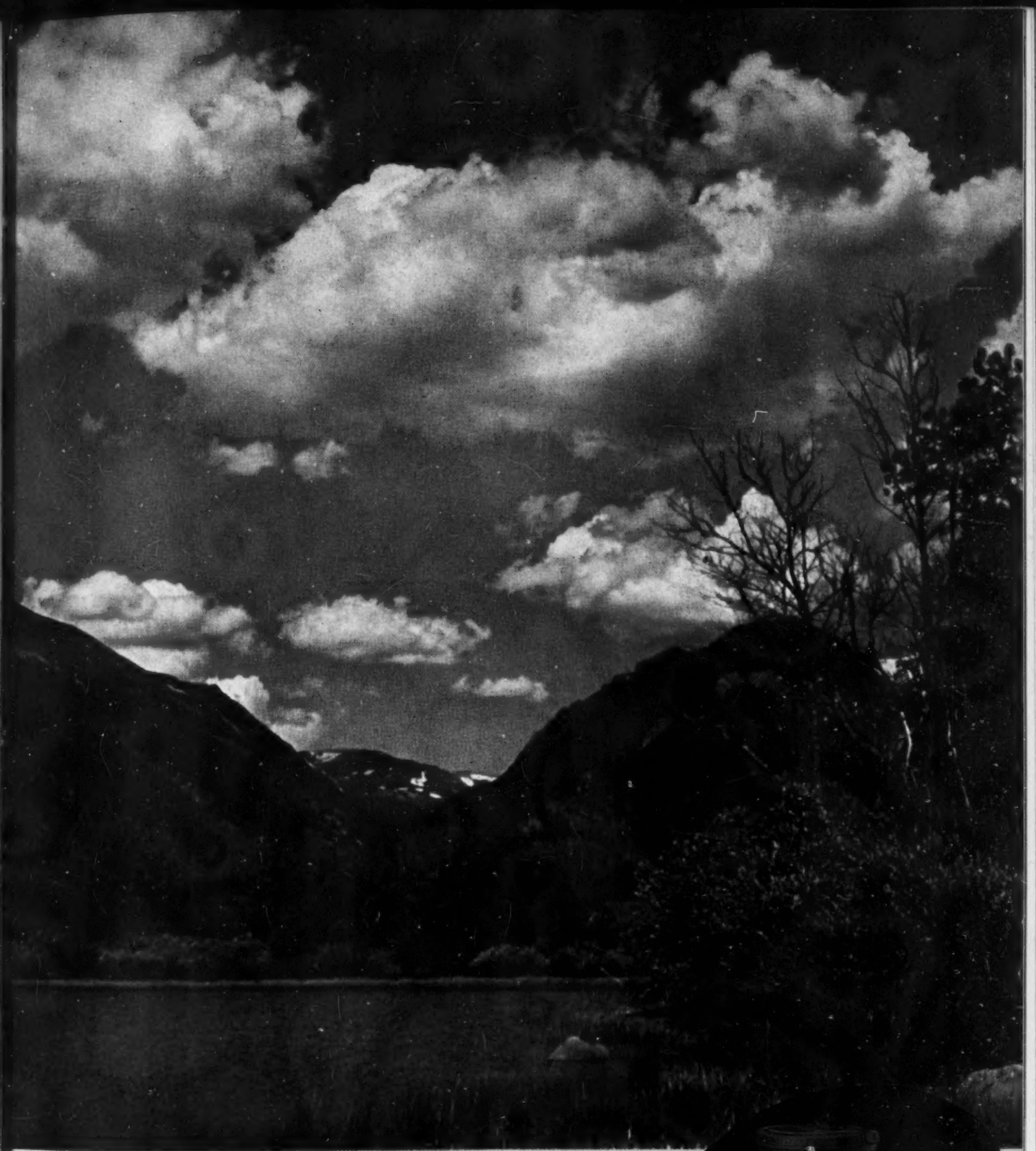
General Chemical Company will be pleased to extend the cooperation of its specialists to Consulting Engineers who are designing sewage disposal plants and to those desiring better results from existing plants. Your inquiries are cordially solicited. Write to

GENERAL CHEMICAL COMPANY

Executive Offices: **40 RECTOR STREET, NEW YORK, N. Y.**

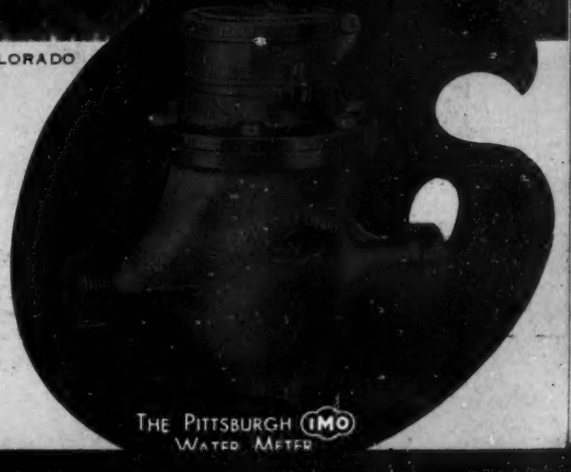
Sales Offices: Atlanta • Baltimore • Boston • Buffalo • Charlotte (N. C.) • Chicago • Cleveland Denver • Houston • Kansas City • Los Angeles • Milwaukee • Minneapolis • Montezuma (Ga.) Philadelphia • Pittsburgh • Providence (R. I.) • San Francisco • St. Louis • Utica (N.Y.) Wenatchee (Wash.) • Yakima (Wash.)

In Canada: The Nichols Chemical Company, Limited • Montreal • Toronto • Vancouver



NATURAL COLOR PHOTOGRAPH, SHEEP LAKE, ROCKY MOUNTAIN NATIONAL PARK, COLORADO

Its silence speaks volumes



THE PITTSBURGH IMO WATER METER

The PITTSBURGH IMO METER

Its silence speaks volumes

JUST as the vast stillness of the towering snow-capped peaks and placid lakes of the Rocky Mountains makes a lasting impression on the observer at first sight, so the quietly operating, accurately measuring, mechanically correct Pittsburgh IMO Meter reacts on the experienced waterworks man.

In the Pittsburgh IMO Meter, silence truly speaks volumes, for its noiseless operation goes hand in hand with an accuracy on both large and small flows that no other meter can match.

Briefly reviewing the history of this revolutionary meter—it was first introduced to the American Waterworks trade less than two years ago, although already proven by thousands of installations on the European Continent. The typical American "show me" attitude justly questioned the claims made for the IMO and challenged its right to compete with existing types which, while leaving something to be desired as perfect measuring instruments, nevertheless had years of successful operation behind them.

This challenge was gladly accepted and as waterworks men, one by one, tested and retested these meters, the word spread that here at last was the one water meter which provided the ultimate for domestic measurement. The IMO was proven to be more accurate than any other type meter, particularly on low flows where such a large portion of revenue was being wasted through the failure of conventional meters to record. And even more remarkable, this high initial accuracy was found to be sustained even after these meters had measured millions of gallons on the most exacting breakdown tests possible to conceive.

Absolute silent operation was another feature noted and appreciated by many water superintendents who had experienced consumer dissatisfaction occasioned by the noise made by existing meters. Finally, they examined the rugged construction, the superior materials used in its manufacture, the unique design in which the operating parts virtually float in the moving stream. They observed the absence of wear after gruelling tests and were convinced that the IMO was built for years of service at rock bottom maintenance costs.

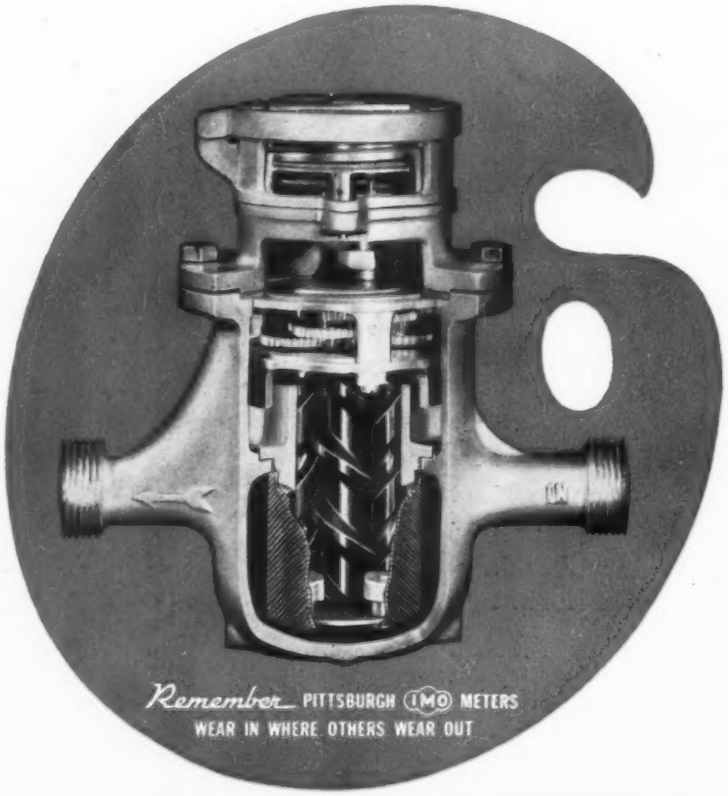
All this is in the past. Today, the IMO is a firmly established product. Pittsburgh IMO Meters are now in use in over 1200 waterworks systems the country over—a remarkable tribute to a remarkable product, and to the foresight of those who desire to give their consumers the best in water service at the lowest possible cost.

Measures the Low Flows

that either escape measurement entirely or are only partially recorded by conventional meters. Factory specifications guarantee accuracy of 98% at 1/4 g.p.m.; 90% at 1/12 g.p.m.; the most stringent accuracy test ever applied to new meters.

Sustained Accuracy

Numerous tests show that even after several million gallons have been measured, Pittsburgh IMO Meters measure slightly better on the low flows than when first put into service and that their accuracy does not change at rates of flow above 1 g.p.m.



Operates Quietly

The basic construction of the Pittsburgh IMO is responsible for its quiet operation. Smoothly turning rotors, precision cut to mesh perfectly, revolve with a semi-floating action as the water flows through the measuring chamber in a straight line. For this reason the IMO can never become noisy; there can be no clicking sound to annoy your consumers.

Costs Less to Maintain

The unique design of the measuring chamber and its semi-floating rotors increases the life of the working parts as compared to conventional meters and insures longer trouble-free service.

PITTSBURGH EQUITABLE METER COMPANY

MERCO NORDSTROM VALVE CO.

NEW YORK · BUFFALO · PHILADELPHIA · DES MOINES · CHICAGO · COLUMBIA

Specify Mathews for this replaceable feature which makes traffic repair or routine inspection a quick, easy, above-ground job. Keep spare barrels on hand for emergencies and spare-time overhauls. Write us for prices on barrels, complete hydrants. Ask for the full story.

CEDAR RAPIDS *KNOWS*
concrete pipe is best for sewers

1887 This concrete pipe sanitary sewer has been in continuous service for over half a century. Concrete is still smooth and dense—sewage scum shown on arch.

TODAY Section of the new 48-inch concrete pipe interceptor through soft fill across Cedar Lake. A fine piece of engineering and construction. Infiltration is practically nil.

CEDAR RAPIDS recently completed a program of sanitary sewer and sewerage works construction based upon a definite city plan and zoning laws which anticipate the probable trend and growth of business and home occupancy for a forty-year period.

It is interesting to note that one of the new precast concrete pipe interceptors relieves the load of an old concrete interceptor constructed in 1887. This half-century old sewer carried all of the East Side sewage of the city until a few years ago, and is *still in good condition.*

2,700 feet of the new interceptor is 48-in. pipe placed in deep tunnel under a street occupied by trunk-line railway tracks. The whole project is carefully planned and constructed to resist all probable super loads. Designed by Howard R. Green Co., Cedar Rapids. F. E. Young, City Engineer.

We will be glad to send literature on concrete pipe or reinforced concrete sewers.

PORTLAND CEMENT ASSOCIATION
Dept. 4-29, 33 West Grand Avenue, Chicago, Illinois

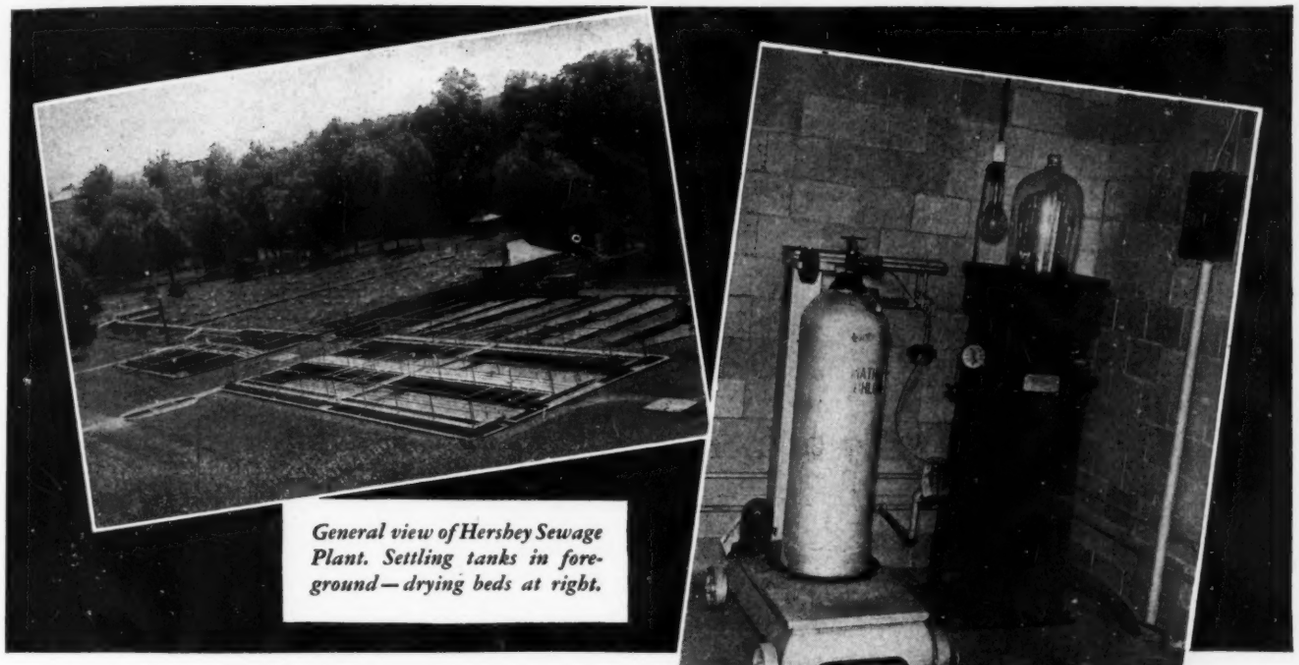
A national organization to improve and extend the uses of concrete—through scientific research and engineering field work.

Where Millions are at stake, Sewers are built of Concrete

FAMOUS TOWN OF HERSHEY, PA.

Maintains Sanitation

THE MATHIESON WAY



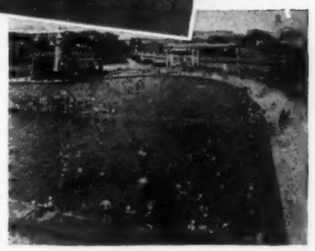
General view of Hershey Sewage Plant. Settling tanks in foreground—drying beds at right.

Cylinder of Mathieson Chlorine attached to chlorinator.

● Hershey, Pa., famed for its cleanliness and fine living conditions, uses Mathieson Chlorine to maintain thoroughly sanitary conditions in swimming pool, municipal water works and sewage plants. And Hershey is only one of hundreds of towns and cities that find Mathieson sanitation service efficient and dependable.

In Mathieson Chlorine you are assured of a pure product, trouble-free containers and valves, prompt delivery service. Keep Mathieson HTH on hand, too, for quick, efficient service when water mains break or other emergencies arise.

Make your plans to attend the 60th annual meeting of the American Water Works Association, Kansas City, Mo., the week of April 21, 1940.



Large swimming pool in Amusement Park of Hershey.

HTH comes in 5-lb. cans with replaceable caps, packed 9 cans to the case; also in 75-lb. drums.

THE Mathieson Alkali Works (INC)

60 EAST 42ND STREET, NEW YORK, N. Y.

LIQUID CHLORINE . . . HTH . . . SODA ASH . . . CAUSTIC SODA . . . BLEACHING POWDER . . . BICARBONATE OF SODA . . . AMMONIA, ANHYDROUS and AQUA . . . PH-PLUS (FUSED ALKALI) . . . DRY ICE . . . CARBONIC GAS

It Can't Happen Here!

Close-up of badly tuberculated pipe.

Close-up cross-section of Mono-Cast Enameline Pipe. Note uniformity of lining and close adherence to pipe metal.

MONO-CAST *Enameline* PIPE

Positively Prevents Tuberculation

. . . definitely lowers pumping costs, maintains permanent high "C" values and permanent carrying capacity. It is regular high-strength Mono-Cast Centrifugal Pipe lined by a new and improved centrifugal method with two coats of special Portland cement mortar intimately bonded to the bare metal pipe surface, and finished with a final coat of asphalt paint. Cuts, taps and threads perfectly without cracking or chipping. Except in very special cases where additional thickness of lining would seem desirable, Mono-Cast Centrifugal Pipe and Fittings are furnished "Enamelined" without additional cost. More than 2,000,000 feet of this pipe now giving highly satisfactory service throughout the United States and in foreign countries. Write for literature.

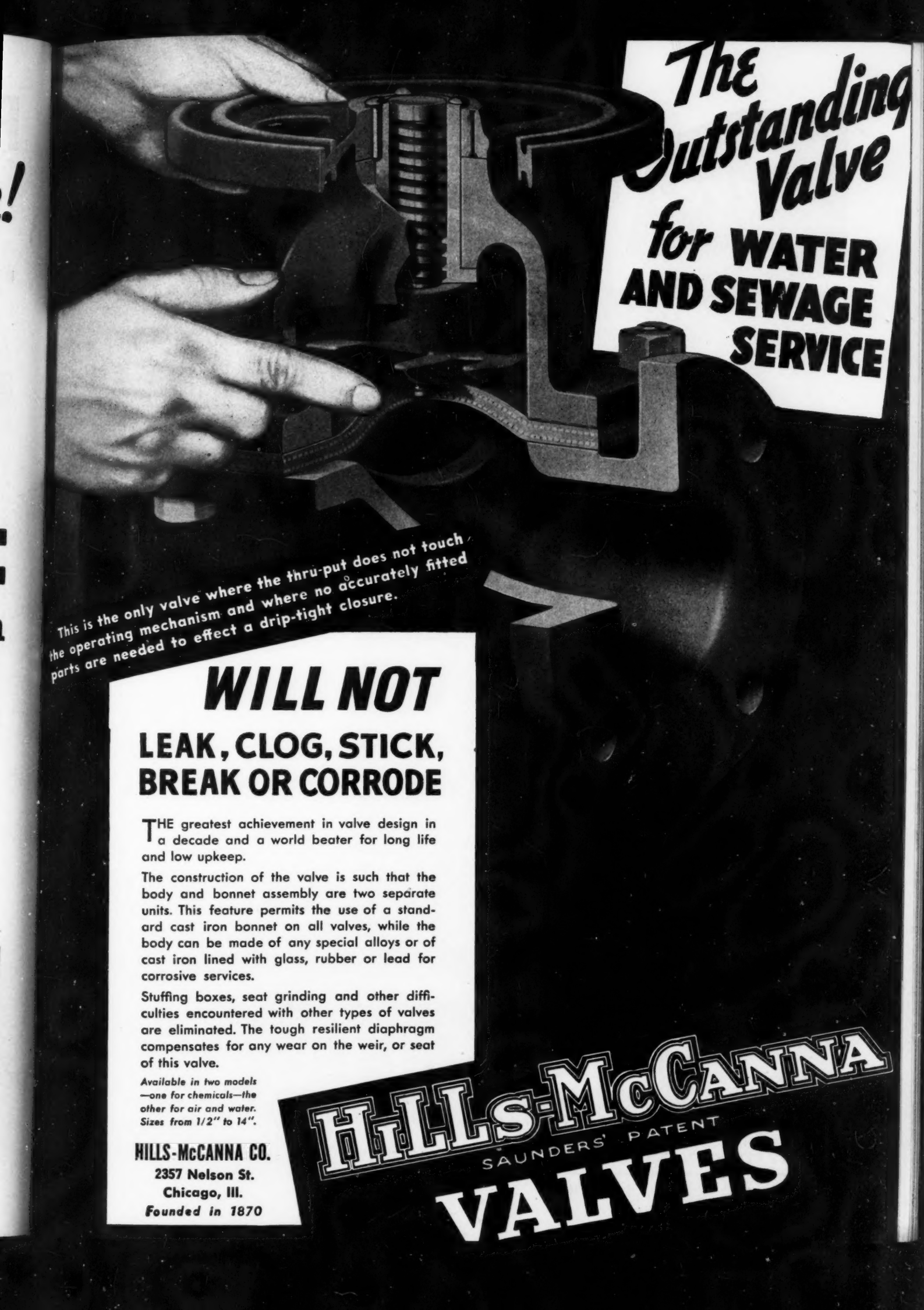
Visit Acipco Booth at AWWA Convention, Kansas City, Apr. 21-25 and inspect 16-ft. length of 48" Mono-Cast Enameline Pipe like those furnished for widely-discussed new water supply line at Wichita, Kan.

AMERICAN CAST IRON PIPE COMPANY

BIRMINGHAM, ALA.

NEW YORK CITY CHICAGO KANSAS CITY MINNEAPOLIS DALLAS
LOS ANGELES SAN FRANCISCO PITTSBURGH CLEVELAND

30" Mono-Cast Enameline Pipe awaiting installation in recently-completed 22-mile water supply line from Table Rock Dam to Greenville, S. C.



The Outstanding Valve for WATER AND SEWAGE SERVICE

This is the only valve where the thru-put does not touch the operating mechanism and where no accurately fitted parts are needed to effect a drip-tight closure.

WILL NOT

LEAK, CLOG, STICK, BREAK OR CORRODE

THE greatest achievement in valve design in a decade and a world beater for long life and low upkeep.

The construction of the valve is such that the body and bonnet assembly are two separate units. This feature permits the use of a standard cast iron bonnet on all valves, while the body can be made of any special alloys or of cast iron lined with glass, rubber or lead for corrosive services.

Stuffing boxes, seat grinding and other difficulties encountered with other types of valves are eliminated. The tough resilient diaphragm compensates for any wear on the weir, or seat of this valve.

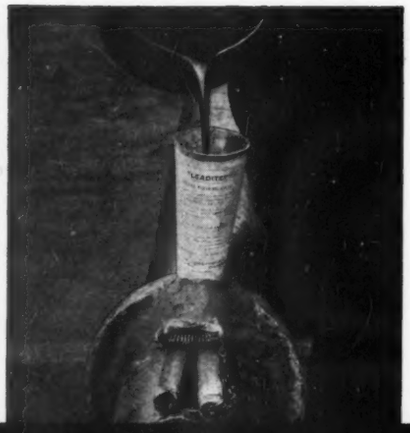
Available in two models —one for chemicals—the other for air and water. Sizes from 1/2" to 14".

HILLS-McCANNA CO.
2357 Nelson St.
Chicago, Ill.
Founded in 1870

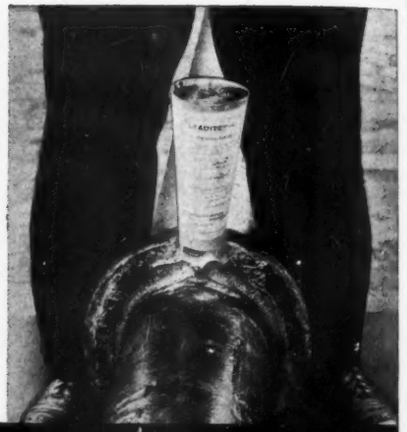
HILLS-McCANNA
SAUNDERS' PATENT
VALVES

Saves TIME AND MONEY ON THE JOB!

1.
Joint Made Ready to Pour



2.
Pouring the Joint



3.
Pouring Completed

4.
Cutting Off Gate

5.
Joint Complete

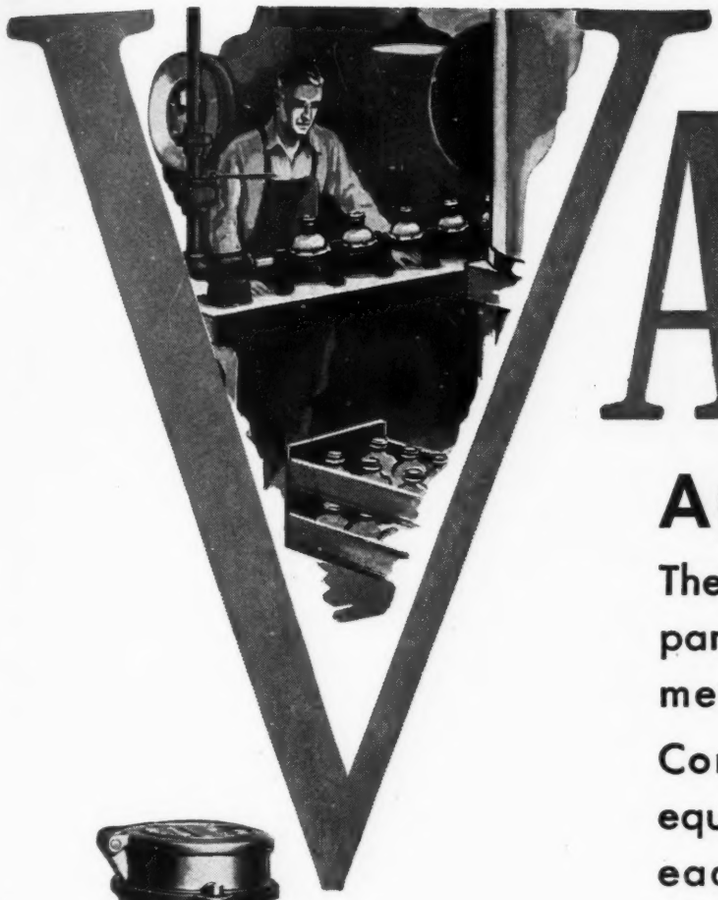
Yes, a real time and money saver
NO CAULKING
—widely used for over 35 years

The Pioneer Self-Caulking Material for C. I. Pipe

LEADITE

Makes a Good Tight Joint which Improves with Age

THE LEADITE COMPANY • GIRARD TRUST COMPANY BLDG., PHILADELPHIA, PA



VALUE

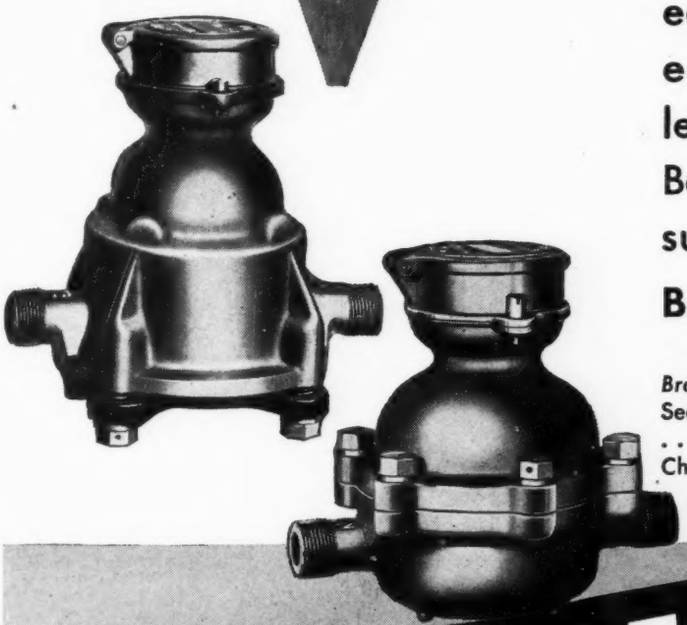
ACCURACY . . .

The Badger Meter Mfg. Company pioneered higher water meter accuracy standards.

Constant improvements in equipment have been made each year to maintain this leadership . . . In specifying Badger Meters you are assured of greater accuracy.

BADGER METER MFG. CO.
MILWAUKEE, WISCONSIN

Branch Offices: New York City . . . Tampa, Fla. . . . Seattle, Wash. . . . Savannah, Ga. . . . Kansas City, Mo. . . . Marshalltown, Iowa . . . Los Angeles, Calif. . . . Chicago, Ill. . . . Waco, Texas . . . Philadelphia, Pa.



DURABILITY
DEPENDABILITY
SENSITIVENESS
LOW COST MAINTENANCE

BADGER *Water* METERS

STREAMLINE COPPER PIPE AND FITTINGS ENDURE THE RAVAGES OF

★ TIME
★ RUST
★ VIBRATION
★ PRESSURE
★ FIRE

★ During the past ten years, Copper Service Pipe connected with STREAMLINE SOLDER FITTINGS has been installed in hundreds of communities throughout the United States and Canada, from corporation to curb stop and on into the building. We have never had a report where Solder Fittings failed or leaked in these installations.

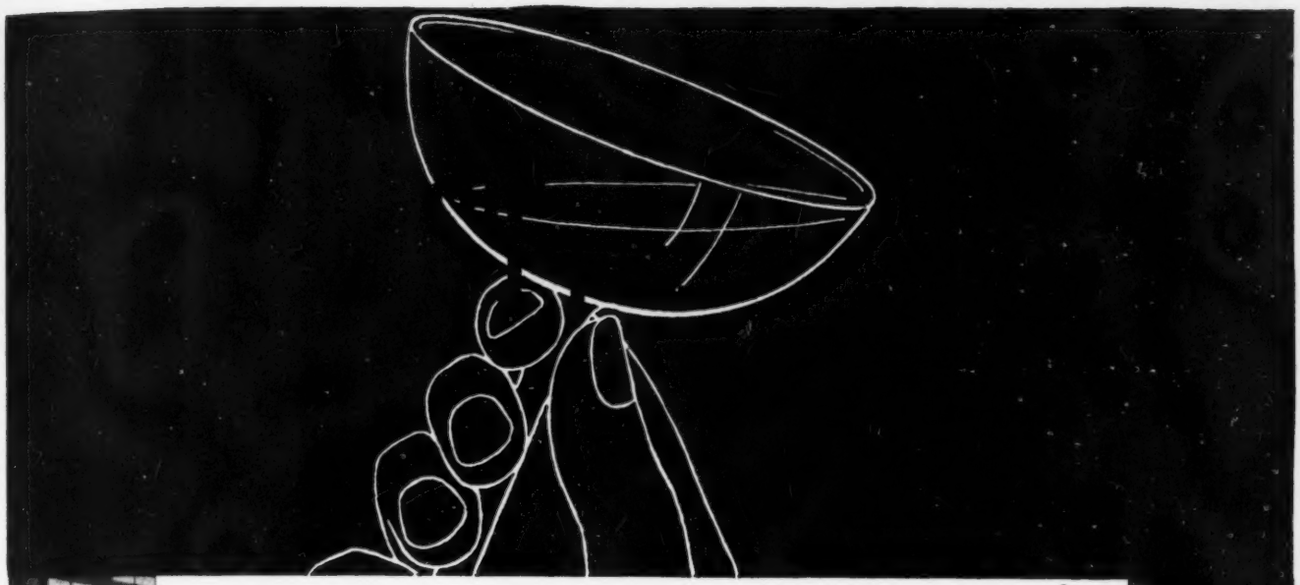
A service line of Type K Copper Pipe connected with STREAMLINE Solder Fittings is exceptionally strong; it is LEAK and VIBRATION PROOF, and —IT CANNOT RUST. Since the conducting area through pipe and fittings is continuously smooth and uniform, there are no anchorage points to build up accumulation of foreign matter. Settlement of filled earth for water mains does not effect it.

STREAMLINE Solder Fitting and Copper Pipe are the most efficient materials for water works use, for general plumbing and heating, for many applications in filtration plants, in aeration lines and in heating coils using the sludge digestion system in sewage disposal plants.

STREAMLINE Copper Service Pipe represents one of the lowest cost forms of insurance that water works officials, who are responsible for the return on a heavy capital investment, can adopt

The word "STREAMLINE" is the Registered Trade Mark of the Mueller Brass Co., Port Huron, Michigan. Genuine STREAMLINE Copper Pipe is made only by this Company and is plainly marked for easy identification.

STREAMLINE
PIPE AND FITTINGS DIVISION
MUELLER BRASS CO.
PORT HURON, MICHIGAN

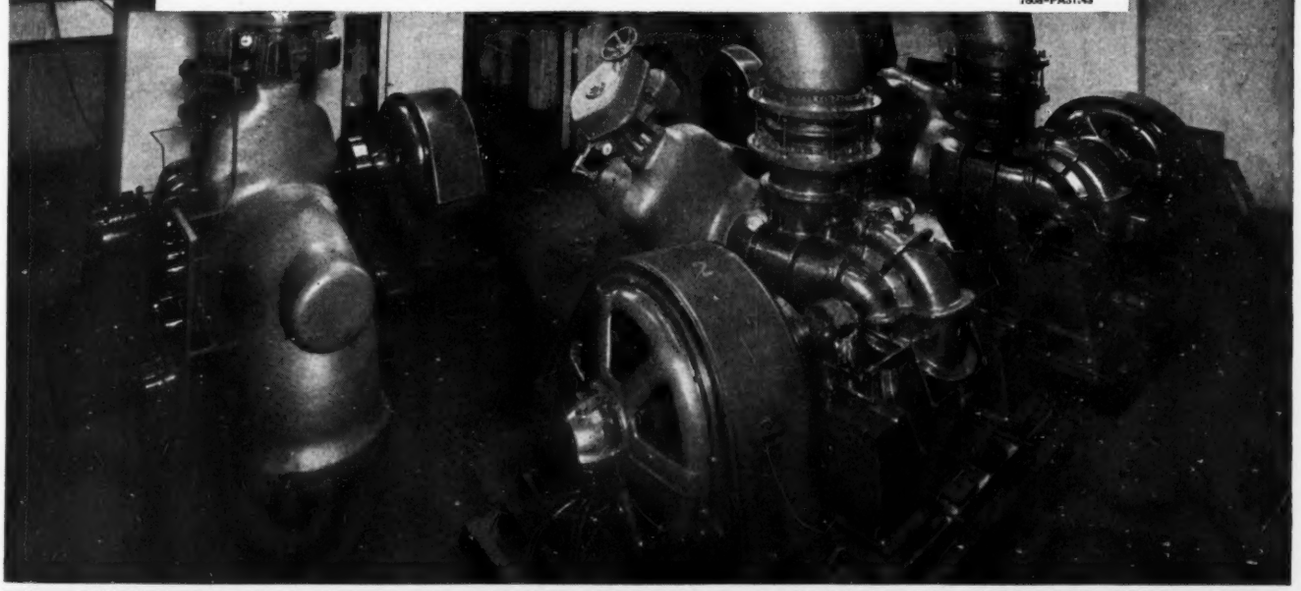


HERE'S to the defenders of the health of millions the world over . . . to the men whose unsung faithfulness to duty keeps water flowing through millions of miles of mains . . . to the men who design and operate the waterworks.

First line of defense of a nation's health —second to no other one factor—is its water supply. This is a responsibility that we of Fairbanks-Morse accept as manufacturers of pumping equipment that must serve faithfully under a wide variety of working conditions. And perhaps that is one of the chief reasons why Fairbanks-Morse Pumps, ranging in a capacity from a few hundred to millions of gallons daily, are familiar sights in waterworks throughout the length and breadth of this country.

Fairbanks, Morse & Co., Department 133, 600 South Michigan Avenue, Chicago, Illinois. Branches and service stations throughout the United States and Canada.

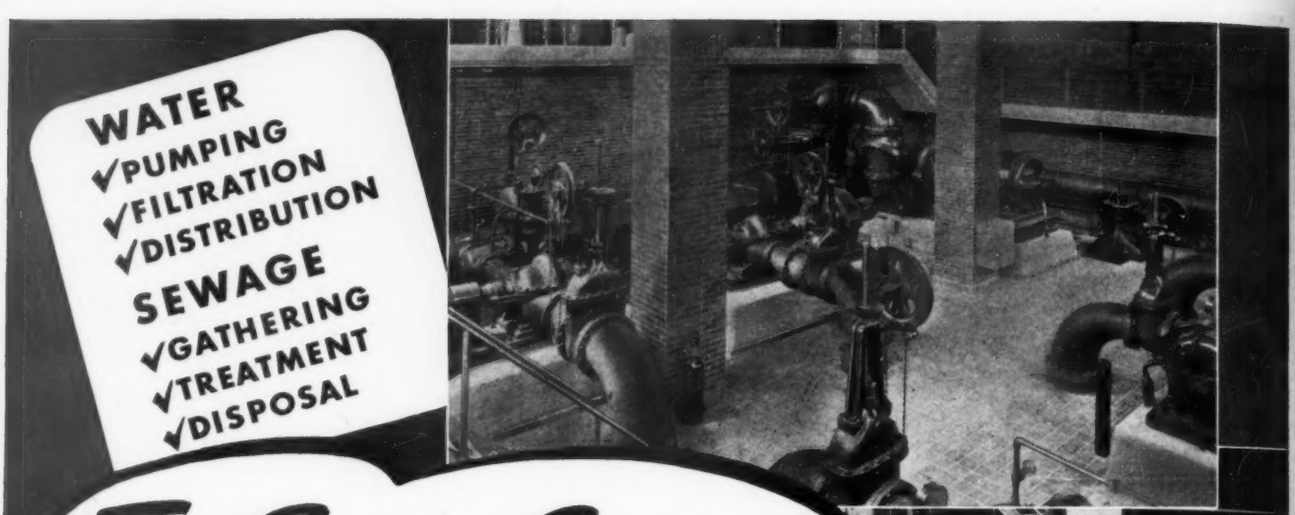
7808-PA31.43



FAIRBANKS-MORSE

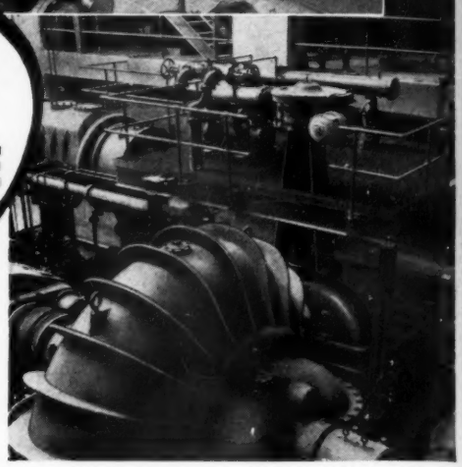
DIESEL ENGINES
PUMPS
ELECTRICAL MACHINERY
FAIRBANKS SCALES
RAILROAD EQUIPMENT
WATER SYSTEMS
WASHERS-IRONERS
FARM EQUIPMENT
STOKERS
AIR CONDITIONERS

Pumps



For Every Service

PREVENTIVE MAINTENANCE COUNSELS CRANE VALVES

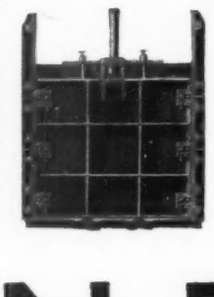


NO one questions the sound economy of Preventive Maintenance. In piping, it's the key to increased efficiency—to low-cost flow-control. Yet, to enjoy its benefits fully, careful buying of valves and fittings is all that's necessary. For, Preventive Maintenance simply means making sure that your piping equipment is right, and best, for the job to be done—right for the safety required. It means fortifying your piping with extra resistance to the stress and strains of working conditions.

To the Water Supply and Sewage Disposal industries, Crane offers complete assistance in applying Preventive Maintenance successfully. With a line of over 38,000 items representing the finest development in flow-control equipment; with unmatched laboratory and plant facilities; and with a vast experience in solving piping problems, Crane can supply the right valve for every service need. And that's where dependability and lasting performance begin.

Can you afford to pass up the advantages of Preventive Maintenance when it costs no more than ordinary maintenance? Talk it over with your Crane Representative.

Be sure to visit our exhibit at the A.W.W.A. Convention, Booths 74 and 75—April 21 to April 25.

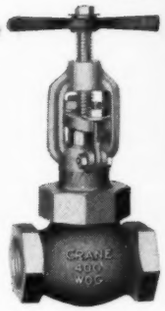


(*Left*) LONGER LIFE IN FILTER WASH LINES—An official test of 5,000 operations showed no sign of any objectionable wear in this new 36″ Crane wash line valve. One of many improvements is the simple disc retracting device. It saves wear by eliminating dragging of discs across seats.

(*Right*) YOU'LL HAVE PEACE OF MIND—and positive control of your system by equipping with Crane No. 480½ A. W. W. A. gate valves. Comply with latest specifications in effect May 1, 1939.

(*Left*) NO RIVETS OR SCREWS TO CAUSE SCORING—in Crane Sluice Gates. The Crane seat mounting method avoids this danger. Made in all sizes and types for seating or unseating pressures.

(*Right*) FOR SAFER CHLORINATION SERVICE—Trimmed with Monel, this specially designed Crane plug type disc valve assures dependable control of chlorine gas lines.



1940 OUR 85th YEAR

CRANE

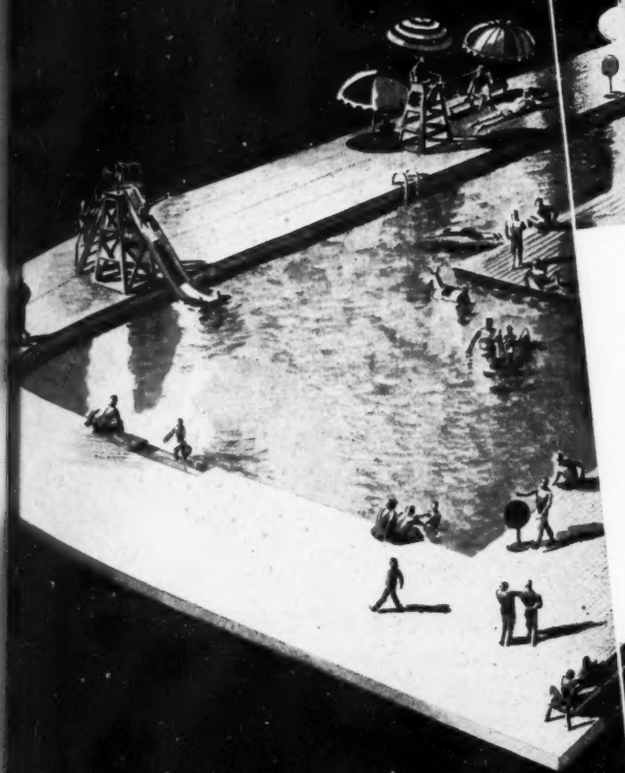
CRANE CO., GENERAL OFFICES
836 S. MICHIGAN AVE., CHICAGO
VALVES • FITTINGS • PIPE
PLUMBING • HEATING • PUMPS

NATION-WIDE SERVICE THROUGH BRANCHES AND WHOLESALERS IN ALL MARKETS

SAFETY
PURITY
CLEANLINESS

for your Community Pools with

DIAMOND LIQUID CHLORINE

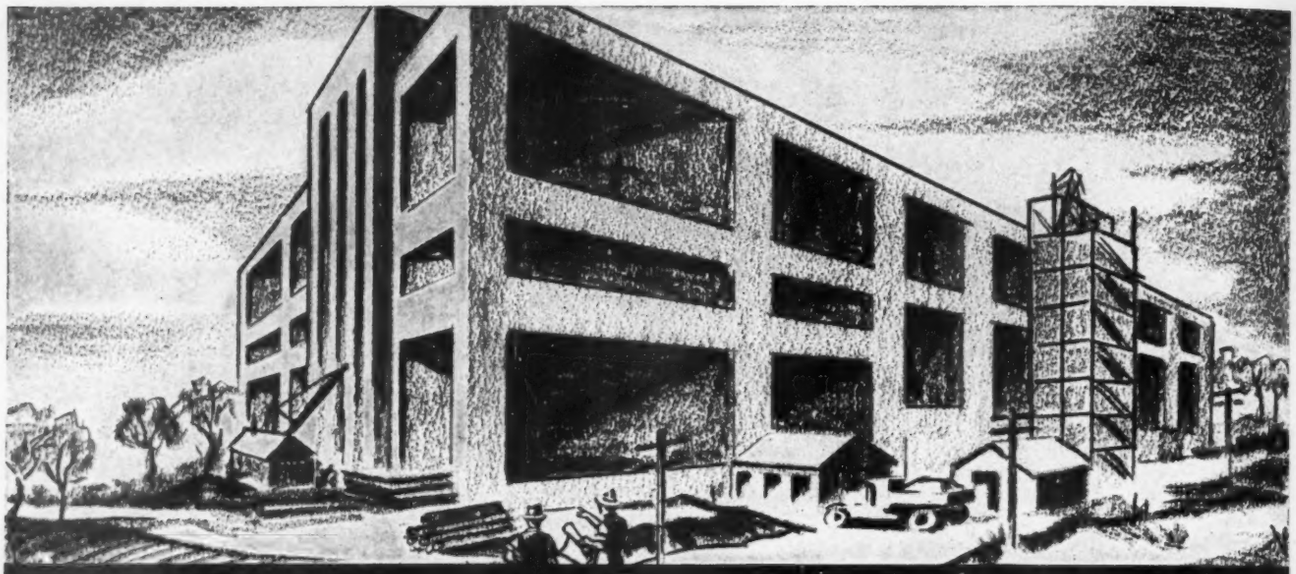


BECAUSE you insist on safeguarding the purity and cleanliness of water used for swimming, you must have a reliable source of dependable Liquid Chlorine. You can't afford to take chances with factors so vital to your success.

We are proud of the confidence placed in DIAMOND by experienced officials everywhere—at the same time recognizing and accepting the responsibility placed upon us by this confidence.

We suggest you do as others have done—get rid of Liquid Chlorine worries by standardizing on DIAMOND!

DIAMOND ALKALI COMPANY
Pittsburgh, Pa., and Everywhere



They Ask Layne BEFORE THEY BUILD

Large and small industries, as well as municipalities, consult with Layne about Well Water Supplies before designing and constructing new buildings, additions or extensions to existing facilities. The reason is obvious. Like gold, water is where you find it. Layne engineers score amazingly high records in selecting sites where ground water may be produced. Furthermore, many decades of world wide experience in developing well water supplies enables them to prove the adequacy and permanence of the supply before the wells are constructed.

From the selection of the site, through the drilling of the wells, supplying and installing proper pumps, to the test and completion of the system, Layne handles the entire job. This plan eliminates the problem of divided responsibility. It insures complete satisfaction.

For free bulletins, address

LAYNE & BOWLER, INC.

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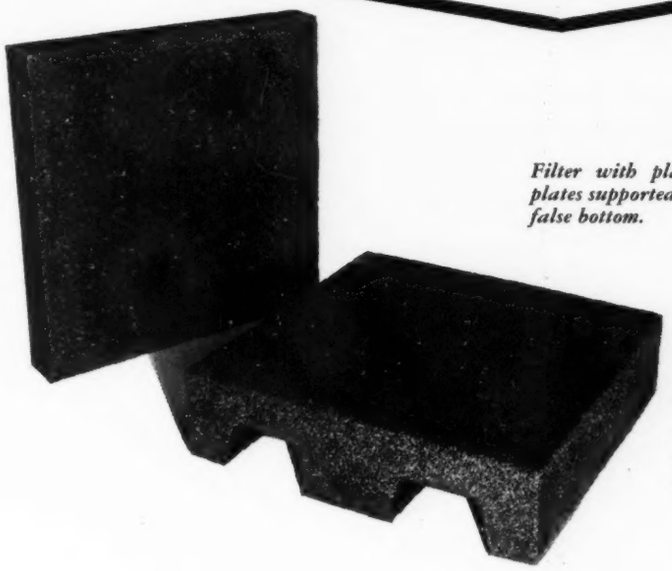
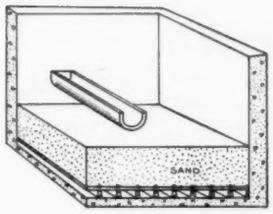
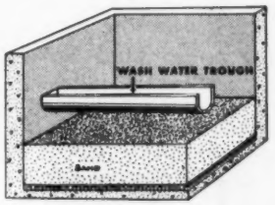


Filter with plain plates supported as false bottom.



Filter with channeled plates directly on floor.



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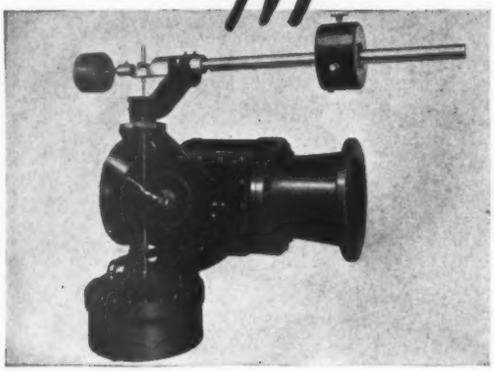

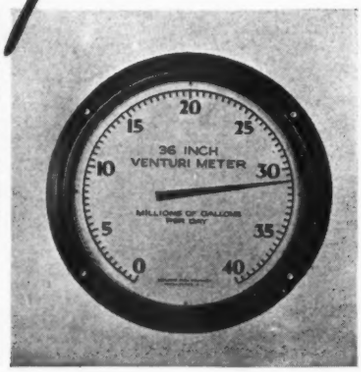

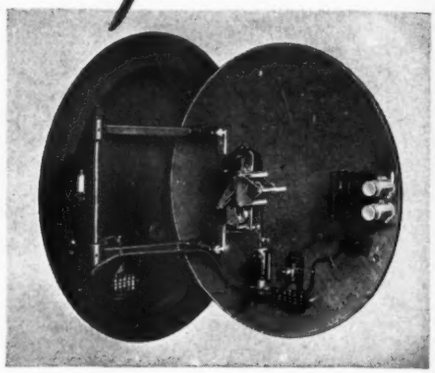

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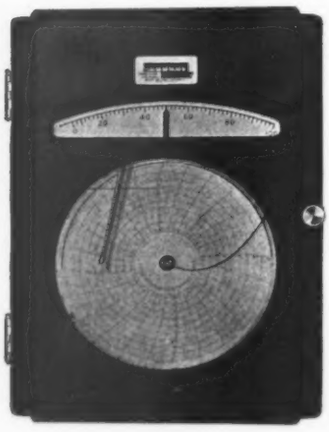

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COMING!

Sewage Works Construction—as Related to Our National Economy

In his stellar analysis and discussion of the past, present and indicated future of sewerage construction and betterments, with particular reference to the soundness of such construction in the National economy of this country, the author has done a masterful job. This address, presented before the Silver Anniversary Convention of America's oldest sewage works association, is generally "good for what ails us." It lays bare questionable methods and economy in sewerage developments and states succinctly what is needed **politically and financially** to advance needed waste disposal betterments represented in millions of dollar value during a planned decade of orderly programmed construction. This paper deserves the widest possible distribution through every governmental agency concerned with stream pollution abatement, and we genuinely regret the unavoidable delay in its printing a single issue. The author is no less a qualified person than—

DR. ABEL WOLMAN, Consulting Engineer
Chairman of the Nat'l. Water Resources Committee, and Head of the Dep't. of Sanitary Engineering, Johns Hopkins University.

Rejuvenating Cast Iron Mains

In Charleston, S. C., a fairly extensive project of cleaning and relining 12,000 ft. of old cast-iron distribution mains in place with cement-mortar by the Tate Process has been completed. Experiences, results and costs of this main rejuvenating project make interesting and profitable reading. Some of these mains had seen service since 1880. The author of this article is known as the "Father of Cement Lined Pipes" in America—

JAMES G. GIBSON, Sup't. and Manager
Charleston, S. C., Water Department

Weed Control in Reservoirs

Was the subject of an interesting article in our July, 1938, issue. The scheme, which from all subsequent reports has proved very effective, involves the use of a chlorinated hydro-carbon which sinks into the mud to poison the actual root growth of weeds. The question of what effect such treatment might have in imparting an aromatic odor or a taste to reservoir waters used for public supplies was immediately raised. Subsequent studies have been made to answer this important question. The results of such studies are presented in an article by—

MORTIMER GIBBONS, Supervising Chemist
Water Department, Rahway, N. J.

"What Cost Low Solids Content of Sludges?"

Might be the caption given a brief analysis of the worth of concentrating activated sludges, or other thin sludges, prior to transfer to heated sludge digesters. The discussion is effectively illustrated with supporting graphs which clearly show the impressive reductions in digester volumes of liquid which can be had with a little attention to sludge thickening to secure improved digester performance and reductions in the problem of supernatant liquor handling. The author—

GORDON J. WIEST, Chemist
Sewerage Treatment Works of
Lancaster, Pa.

Licking Cold Weather Troubles with Chlorinators

Is one of those Dear Bill letters from one "Super" to another which passes on valuable information without the labor of "preparing a paper." These helpful suggestions, pertaining to chlorinator maintenance, come from—

DON C. CALDERWOOD, Operating Engineer
Pennichuck Water Co., Nashua, N. H.

"25 Signs of the Master Salesman"

Is an article by a "Master Salesman" which reveals his conception of what "Master Salesmen" are made of. We have purposely scheduled this article for the benefit of the many salesmen who admit that they do "glance through" *Water Works and Sewerage*. The Author—

J. G. FREDERICK
New York City

VOL. 87, No. 4 — April, 1940

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WATER WORKS & SEWERAGE

VOL. 87, NO. 4 *A Gillette Publication* APRIL, 1940

MILWAUKEE'S WATER PURIFICATION PLANT

By JOSEPH P. SCHWADA—City Engineer
MILWAUKEE, WISCONSIN

MILWAUKEE is fortunate in having an unlimited supply of water at its very door, Lake Michigan, and since 1874, when the original municipal water works was completed, has taken full advantage of this generous source. Since that time, too, it has made every reasonable effort to expand and improve its water supply facilities including intakes, tunnels, pumping stations, and distribution systems, in order to meet the growth of the city and neighboring political subdivisions supplied with water. Unfortunately, however, these several betterments did not include adequate provisions looking to improving water quality. In consequence, consumers received water that periodically was very unsatisfactory.

The Author

In 1911 a commission of sanitary engineers recommended that a filtration plant be provided immediately for the purification of the water supply. This was followed by seven similar recommendations, the

The author of this article has every right to the title "Victorious Veteran". He is deserving of a civic citation for having come through his campaign wearing the smile of victory.

It took no little perseverance or tenacity on his part to repeatedly, and practically continuously wage the battles which he has carried on during the better part of two decades. These were the battles looking to securing a water purification plant and a better water for the people he has so well and conscientiously served. Now the last battle has been fought and "Jo." Schwada has to show, for his long fight, a five million dollar filter plant at Milwaukee's front door, capable of turning out three hundred million gallons of wholesome water daily.

Milwaukee possibly has the strangest history ever recorded in respect to the sanitary achievements of a City. As Mr. Schwada remarks, a small minority of citizens has since 1911 repeatedly been able to defeat proposals to construct a modern purification plant, capable of supplying a palatable and safe water for the community. As a result, Milwaukee has had on many occasions to stomach chlorine or chlor-phenol "cocktails", and has suffered in respect to its public health records. Now, follows, the strange picture of the situation.

One of the chief reasons for the success of the opposition which blocked filtration for so long a time can be explained by the success which the minority attained in persuading the people of Milwaukee that the new activated sludge sewage treatment plant would render unnecessary any expenditures for water purification, and would completely solve the health and the taste problem. By local experts, of this they were assured; so, Milwaukee spent millions first on sewage treatment, only to find in the end that those claiming that, thereby, "the cart was being put before the horse" had been right from the beginning. In 1933 Milwaukee came to a full realization that the "cart" had not proved sufficient, and set about procuring the "horse".

Great is the credit due City Engineer Schwada for his constant fight which has not brought to Milwaukee the last word in filter plants—a "horse" which can not be outshone by Milwaukee's very fine "cart" on Jones Island.

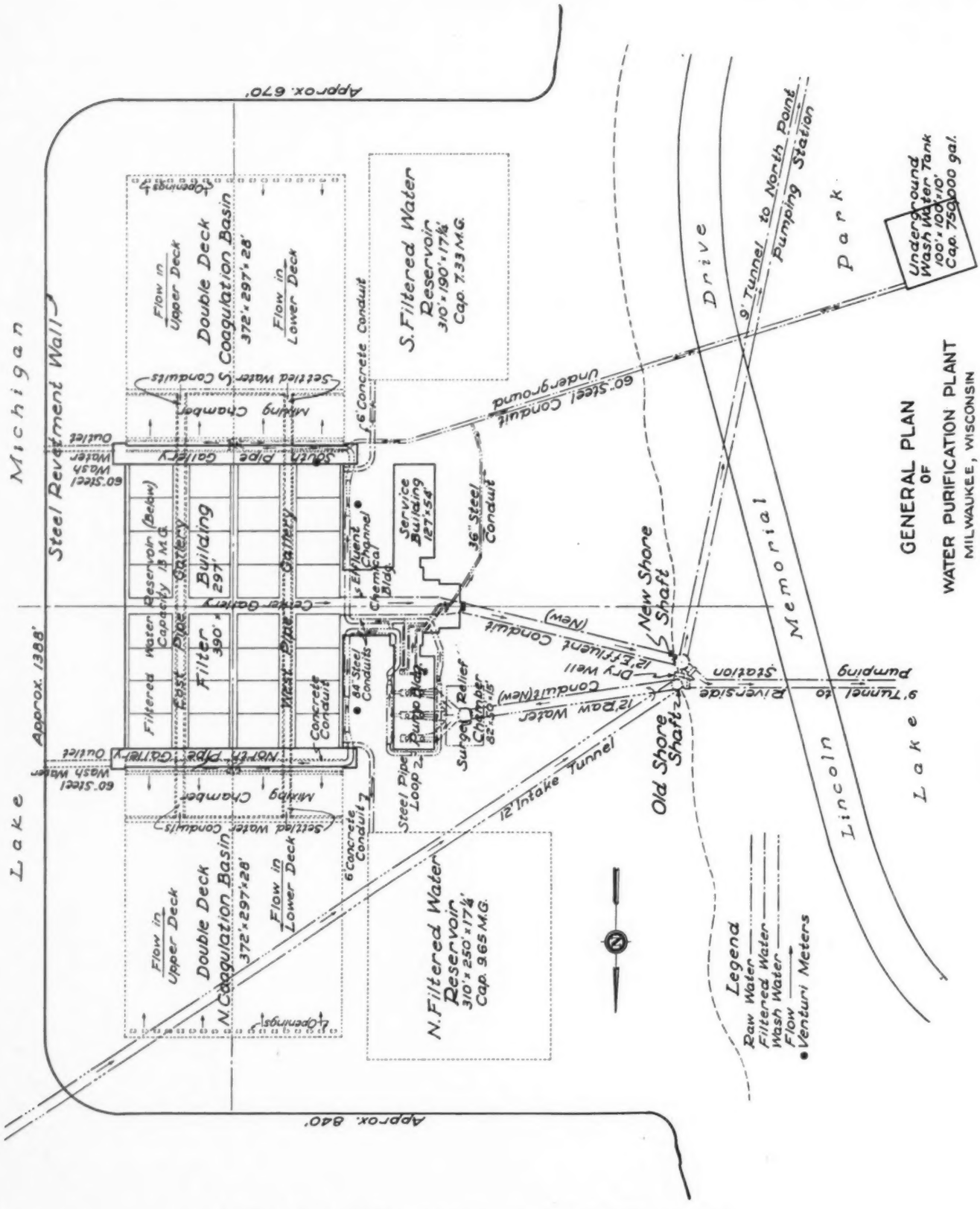


Fig. 1—General Plan of the Milwaukee Water Purification Plant

last by the United States Public Health Service in 1931. Each time that a plant was seriously considered, however, it was opposed by a small minority of citizens and not until 1933 were arrangements made to build a plant. At that time the Common Council authorized its construction, and the Public Service Commission of Wisconsin issued a certificate of necessity and convenience, which was upheld by the Circuit Court of the State, despite the opposition of the minority. Early in 1934 a contract was entered into with the Federal Administrator

of Public Works. Immediately thereafter plans and specifications were started, construction work was begun, and in July, 1939, the plant was placed in operation.

Plant Location

Milwaukee's Water Purification Plant is located upon the shore of Lake Michigan near the north end of the city and occupies a part of the beach and filled ground enclosed and protected by a revetment wall. The total area of the site is approximately 26 acres, and the area occupied by plant structures proper is approximately 12 acres. The site is at a point where the Linnwood Avenue intake tunnel, placed in service in 1918, terminates in a shore shaft and connects with tunnels that conduct the water to the Riverside and the North Point Pumping Stations. By locating the plant here the investment, especially in new tunnels, is reduced to a minimum (see Fig. 1).

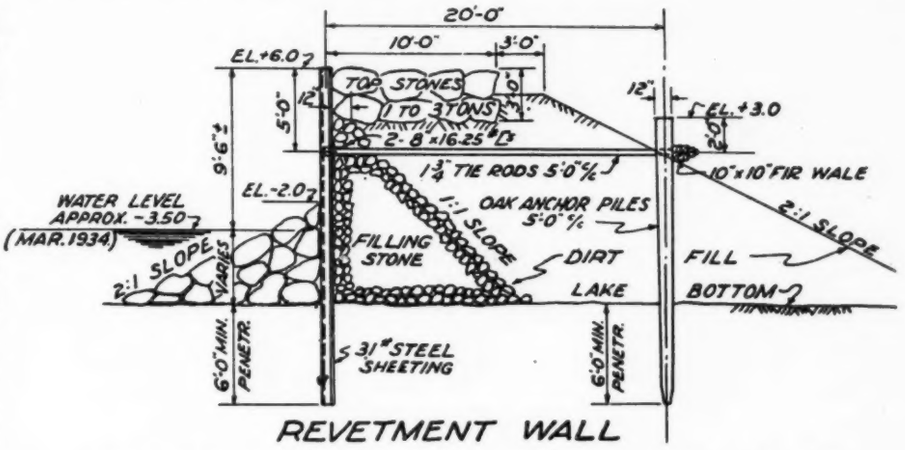


Fig. 2—Section Through Revetment Wall Constructed Out into the Lake

The enclosing revetment wall, constructed out into the lake (Fig. 2), consists of a single row of steel sheet piling tied back to a row of wood anchor piles. On the lake side the wall is protected along its base by 1 to 3-ton stone, and on the shore side it is backed with a stone and earth fill, topped and protected with 1 to 3-ton stone. The sheet piling is of the arch web continuous interlock type with a thickness of ⅜" in the web and side walls, a weight of 31 pounds per square foot of wall, and with a 15" center to center of interlocks. Before the wall was constructed, a test wall 75 feet long was driven with various types of steel sheet piling, and the information thus obtained was used in the final design of the revetment wall. The sheet piling is driven to refusal, at a depth of about six feet below lake bottom.

The Plant in General

The plant consists of four inter-connected buildings and several underground structures (Fig. 1). The Chemical Building is flanked by the Pump Building (north), the Service Building (south), and to the east is the Filter Building. The Surge Relief Chamber, Coagulation Basins, Filtered Water Reservoirs, and Wash Water Tank are all underground.

The Surge Chamber was constructed directly over the raw water tunnel. The so-called Wash Water "Tank" is in reality a concrete underground reservoir located on top of the bluff in the park, a short distance west of the plant. A third Filtered Water Reservoir, or clear well, forms the sub-structure of the Filter Building.

Type and Capacity

Of the mechanical rapid-sand type, the plant has a rated filtration capacity of 200,000,000 gallons per day. Such is based on the conservative rate of 2 gpm. per square foot of sand area, or a rate of 6¼ mgd. per filter for 32 filters. It is believed that the plant can be operated at a maximum rate of 300 mgd. without any jeopardy whatever to purification efficiencies.

The three Filtered Water Reservoirs have a total capacity of 30,000,000 gallons. Th Wash Water Tank has a capacity of 750,000 gallons.

Provisions have been made, for later doubling the capacity of the plant, without interrupting operations of the present plant or making any material changes within it except replacing some of the low-lift pumps with larger units.

Recognition was also given to the possibility of constructing a second purification plant on the south side of the city, instead of increasing the capacity of the existing plant, and the present layout was prepared accordingly.

Water Flow Through the Plant

Raw water is drawn from the short shaft of the intake tunnel through a 12-foot concrete conduit which divides into three branches, each branch leading to two low-level pump suction pieces (Fig. 1). Motor-driven centrifugal pumps raise the water into the Coagulation Basins. From this point it flows by gravity through the remainder of the plant to the Filtered Water Reservoirs.

The discharge from the centrifugal pumps passes horizontally through check valves into a steel pipe encased in concrete and encircling the outside of the Pump Room (Fig. 3) about 10 feet under ground level. Two 84" steel conduits conduct the water from the discharge end of the loop through the subbasement to the Chemical House to the Coagulation Basins, one connecting to the north and the other to the south Coagulation Basin. These conduits are cross-connected so that either side of the loop can deliver to either Coagulation Basin. Motor-operated butterfly valves are located at various points in the loop for that purpose.

Chemicals, including lime, alum, chlorine, carbon, and ammonium sulphate, are applied to the raw water in the 84" steel conduits in the sub-basement from the chemical feed equipment in the Chemical House above. Provisions have also been made for pre-ammoniation, if desired, by introducing ammonium sulphate into the raw water tunnel between the shore shaft and the Pump House, and carbon into the settled water as it leaves th Coagulation Basin on its way to the filters. Additional provisions have been made for applying ammonium sulphate and chlorine to the filtered water as it passes through the main effluent channel of the Filtered Water Reservoir on its way to the pumping stations. Still further provisions have been made for introducing chlorine into the water in the new short shaft (Fig. 1), at the inlets to the pumping station tunnels. These will be used only if a serious power interruption shuts down the plant and an unfiltered but chlorinated supply has to be furnished temporarily.

The chemically dosed water enters the mixing and

flocculating chambers, where it is stirred by mechanical agitators, of the horizontal paddle type, revolving between hanging wooden baffles. Then it is discharged into the double-deck sedimentation basins where at settling velocities the water flows through the lower deck, up through openings in the partition or floor, and then back through the upper deck toward the inlet end of the basin or toward the Filter Building (see Figs. 1 and 4).

After the water has passed through the sedimentation basins, it enters collecting conduits which connect with settled water conduits that conduct it for distribution to the thirty-two filters in the Filter Building. The settled water flows into the filters and passes through 27" of sand and 24" of gravel to the perforated cast iron grid collector system on the bottom of each filter box.

The filter effluent discharges through automatic rate-of-flow controllers to the Filtered Water Reservoir below. From here it can flow through separate conduits to the two underground reservoirs. From the Fltered Water Reservoirs the flow is through a channel into a 12-foot concrete conduit to the new 18-foot diameter shore shaft. The latter is constructed adjacent to the original shore shaft, now serving as the raw-water intake shaft. The new shaft is connected through gates to the 9-foot diameter tunnels leading to the North Point and the Riverside Pumping Stations. The connection with the original shore shaft has been valved off with two gates, so that there can be no accidental contamination from the raw water intake into the filtered water shaft. In the event of a serious interruption of power on both power lines, the gates can be opened and an untreated but chlorinated supply of water furnished.

Surge Relief Chamber

The surge relief chamber is just west of the Pump House. It is an underground concrete structure 82 feet by 50 feet and 15 feet high, set on top of a 20-foot diameter shaft which extends down to the raw water conduit where it divides into the three branches leading to the pump suction pieces. The top of the chamber is 1.5 feet below the present ground level.

Two sluice gates, each 5×10 feet with a support between them, are installed in the conduit where it connects with the shaft. A third sluice gate, 9×9 feet, is installed on the north side of the shaft where provisions have been made for a future connection with another raw water intake tunnel.

In case of a sudden interruption of power at the pumping station the check valves will close, and the surge from the intake tunnel will cause the water to rise in the 20-foot diameter shaft and enter the surge chamber. In this way the chamber supplements the intake short shaft and relieves the pressure due to surge.

Pump Building

The Pump Building is 127×54 feet inside. A visitors' gallery 10 feet wide extends across the pump room at the south end at the level of and connecting with the side lobby in the Chemical Building (Fig. 3). Directly

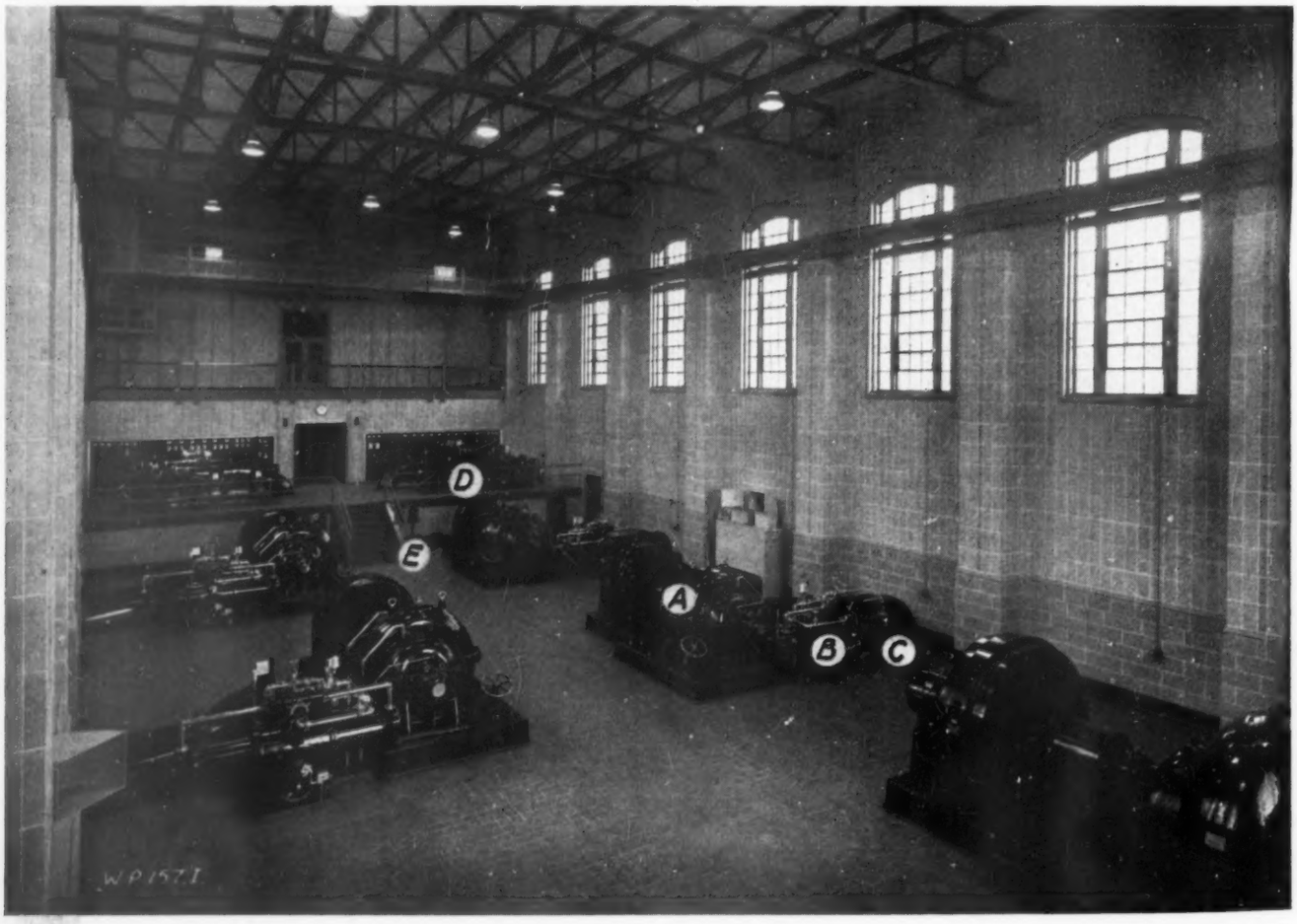


Fig. 3
Pump Room (A) Low-Level Pump; (B) Check Valves; (C) Semi-rigid Coupling in Discharge Piping; (D) Wash Water Pumps; (E) Vacuum Pumps

below this gallery is a switch room and switchboard. In front of the latter is the wash water pump platform that connects through to the Chemical Building.

On the main floor one 75 mgd. and four 50 mgd. pumping units are installed. These units pump the raw water against a head of 30 feet into the coagulation basins. On the wash water platform there are two 20 mgd. pumping units which pump filtered water from the effluent channel against a head of 80 feet into the wash water reservoir on the bluff above the plant. Each pump is driven by a synchronous motor having unity power factor with direct connected exciters. The control is mounted on the front wall (forming the switchboard) of the enclosed switch rooms and is of the automatic full voltage type.

The foundations supporting each pumping unit also support the pump suction and discharge valves. The foundation design was greatly simplified by the installation of butterfly type valves on the suction side of the pumps. These valves present the advantage of small face to face dimensions, and small clearances perpenidcular to the center line of the pipe. The pump foundation is separated from the building by a cushion of cork. An expansion joint is installed below the pump suction valve and connects to the pump suction piece. A semi-rigid coupling is installed in the pump discharge piping. If a pump or check valve is to be put out of service for repairs, one ring in the coupling can be replaced with a blank flange.

Discharge check-valves are of the cone type which open automatically when the pump is up to full speed, and close automatically whenever the pump unit is shut down or power failures occur. Power to operate the check valves is supplied from a separate hydro-pneumatic pressure system. Two-thirds of the volume of the pressure tank is normally water and one-third air under approximately 100 pounds pressure. The tank and piping are sized to provide dependable hydraulic power sufficient to close eight discharge valves before reversal of rotation of any pumping unit can take place. Thus, should a power outage occur the station would go down without a serious incident, regardless of the number of pumping units in operation at that time.

All hydraulic pressure, priming, heating and electrical piping is exposed in a tunnel under the pump room floor. The tunnel is 4 feet wide and 6 feet high and extends the length of the pump building along its center line, terminating under the wash water pump platform. Branch tunnels are carried out under each low level motor, and low level pump and discharge valve.

The pumping units and major piping are painted a glossy black, and all small piping and trim are chromium-plated. The switchboard is finished in a dull black.

Electric Power

Electric power is supplied by the Wisconsin Power Company, from two different plants, through twin underground power lines run in separate duct systems well separated from each other. One is a 26,400-volt line, and the other a 13,200-volt line. The lines terminate in the city-owned sub-station just in the rear of the pumping station. The sub-station includes two 2,000 K.V.A., 60-cycle, 3-phase transformers with multiple series winding, to accommodate either the 26,400 or 13,200 volts, on the high service side and the 2,300 volts low service.

The 2,300-volt leads from the power transformers are taken underground into the line breakers of the switch rooms in the Pump Building. Each 2,300-volt lead feeds

Fig. 5

Storage Room, Showing Method of Handling Bagged Chemicals on Skid-Platforms. In this instance, activated carbon.

a separate bus. To one bus is conected four of the large synchronous motors, and three to the other bus. All auxiliaries can be connected to either bus, and a bus tie is provided. Normally the tie is closed and power is obtained through one line only. The oil circuit breakers and bus structures are placed along one wall of the switch rooms.

An auxiliary feeder from each 2,300-volt bus is run through the plant and a tie is run between them at the extreme ends. Three banks of distribution transformers are fed from the feeder system. One bank is located in the sub-station, and two in vaults near the center of the filter building. Each bank consists of 3 25-KVA single phase transformers 2300-460 volts connected delta-delta for auxiliary power and 1 50-KVA single phase transformer 2300-230/115 for lighting. Nofuze type distribution cabinets for both auxiliary power and light are set up near each transformer bank and secondary ties are run between cabinets. Ample switching facilities are provided in both the feeder and secondary circuits. Power circuits are wired 3-wire 460-volt 3-phase and

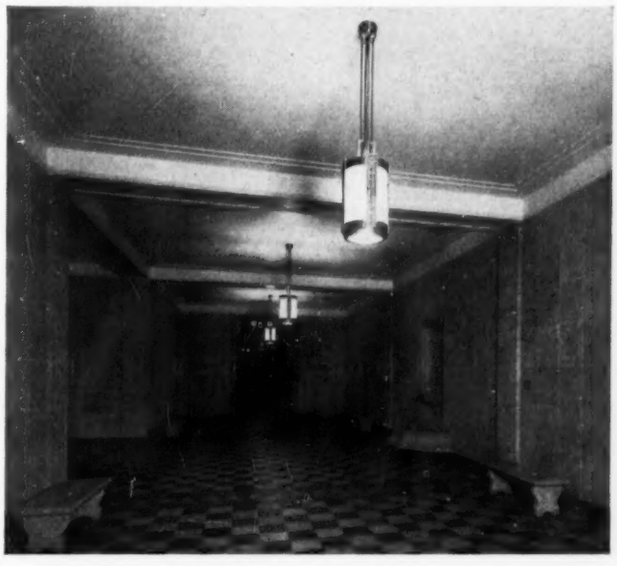


Fig. 4—Main Lobby of Chemical Building

Stairway leads to Main Aisle of Filter Building. Offices, Conference and Lecture Rooms on right and left. The walls are of soft tan Maukate stone, the floors of green slate and green marble in 12" squares.

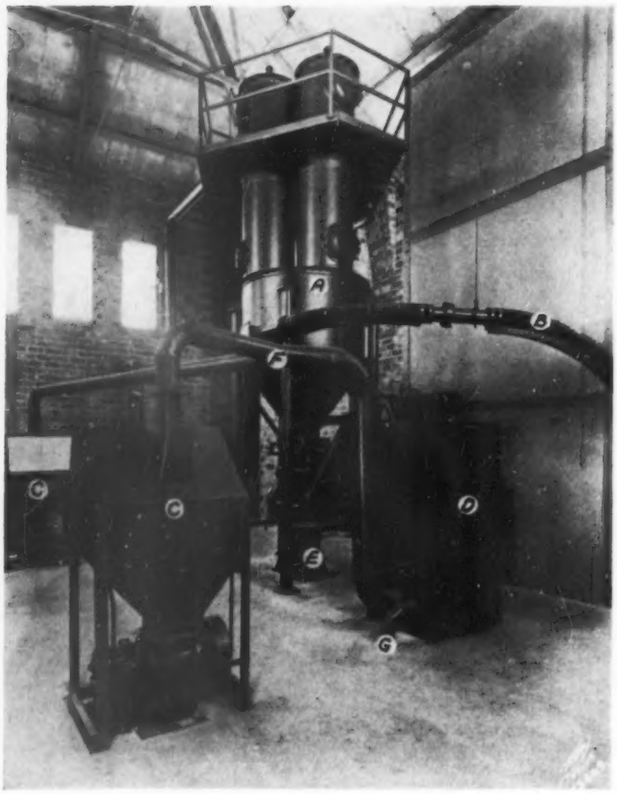


Fig. 6
In the Tower of the Chemical Building. (A) Pneumatic Receiver with (B) Conveyor Pipe from Reclaiming Basins in Service Building; (C) Carbon Bag-Dumps; (D) Air Filter; (E) Spout to Spiral Conveyor; (F) Dust Exhaust Pipe from Bunkers.

lighting circuits are wired 3-wire 230/115-volt single phase.

Lighting Facilities Emphasized

Lighting fixtures were studiously selected for each specific illumination problem, depending on place and purpose. Over each filter bed two 1000-watt special Holophane type vaporproof floodlights are installed. These provide 20-foot candles of excellent illumination on the water surface (and beneath) with no glare or images from the operator's position. (See Fig. 13.) Aisles are illuminated by means of 500-watt overhead bronze lanterns on 20-foot centers. Pipe galleries, subbasements, bag storage floors, etc., are also illuminated with a compact vaporproof type of fixture. Thousand-watt high bay lighting fixtures are installed in the pump room to provide a uniform intensity of 15-foot candles on the pumps.

Time and Communication System

A complete synchronous electric clock system is installed. The installation consists of 21 clocks and 55 recording instrument drives. All clocks will operate during power interruption.

A selective talking, selective ringing, dial type automatic telephone system, including an auto-call system, is installed. This provides 17 telephones and 29 signal bells.

Chemical Building

The Chemical Building, for convenience in description, may be considered in two parts, namely, the six-story part with the tower and the two-story part connecting with the Filter Building. The former houses the dry chemical feed equipment. It contains also on the first floor, just inside the main entrance, a rotunda and lobby (Fig. 4), administration offices, conference and lecture rooms, and wash rooms; and on the second floor a chemist's office and the laboratories. An elevator runs from the basement to the sixth floor. The two-story section houses the gaseous chemical feed equipment. It also contains on the first floor a connecting corridor from the main lobby to the center gallery of the Filter Building, a telephone switchboard room, and a janitor's room, and on the second floor an aisle at the level of, and connecting with, the main aisle in the Filter Building, a meter and gauge room, and several wash and store rooms.

On the third, fourth, and fifth floors, separate rooms with ready access to the elevator have been provided for bag storage. Here carbon and ammonium sulphate are stored (Fig. 5).

Chemical Handling and Storage

The equipment installed in the tower of the Chemical Building (6th floor), consists of a pneumatic conveyor (Fig. 6) by means of which the alum and lime, received in bulk, are elevated from the bins in the Service Building. Also, in the tower are the two carbon bag dumps, an air filter, and the conveyor vacuum pump. The chemicals are elevated and then discharged downward through the floor in rectangular spouts into short 12″ spiral conveyors which in turn discharge into two other 12″ spiral conveyors located directly on top of the two steel storage bunkers. From the latter conveyors the chemicals are discharged into any one of the several compartments in the bunkers (Fig. 7).

The carbon bag dumps are located on the sixth floor so that they discharge through pipes directly into the carbon compartments in each bunker below. The hoods of the carbon dumps and the tops of the carbon compartments in the bunkers are connected by suction pipes to the air filter for the removal of dust. The vacuum pump is connected to the pneumatic receiver and is a part of the conveying system.

Ammonium sulphate, which is delivered to the plant in bags, is placed directly into the compartments through openings in the bunkers from a steel runway, which is on a level with the fifth floor of the Chemical Building. Carbon, also delivered in bags, can also be placed into the compartments at the same level instead of through the carbon dumps on the sixth floor, if such is desirable.

Chemical Feed Facilities

The dry chemical feed room and storage bunkers occupy a space 63 feet long and 43 feet wide in plan and extend from the second to the fifth floors, with the covers above the fifth floor level. The bunkers including the sloping covers are 22 feet high and 21 feet 6 inches wide near the top. Each bunker is divided into compartments for the storage of lime, alum, ammonium sulphate, and carbon.

Weigh hoppers are suspended above the two rows of feeders in the Chemical Room directly below the steel bunkers. At present there are installed four hoppers for carbon, one for lime, three for alum, and three for ammonium sulphate.

An electrically operated continuous feeder of the gravimetric type is installed under each hopper by means of which the chemicals are fed to a variety of solution devices. These feeders are enclosed in dust-tight cabinets and are capable of being adjusted over a 75 to 1 ratio (Fig. 7).

The alum is dissolved in a stainless steel solution tank equipped with an electrically driven propeller. The

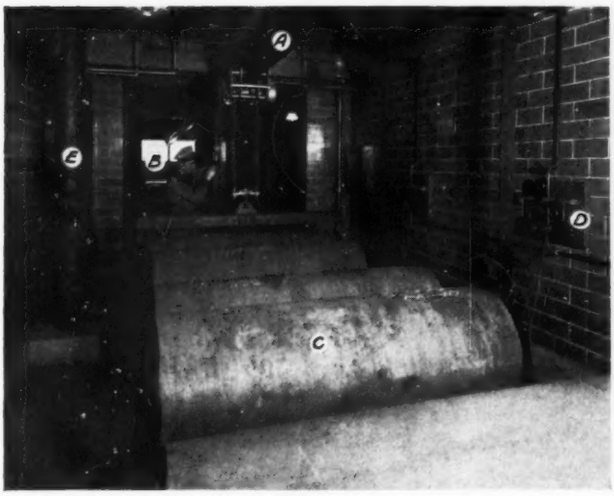


Fig. 8
Chlorine Container Scale Room. (A) Mono-rail System extending through to (B) Store Room; (C) Ton Containers; (D) Sub-Panel; (E) Chlorine Solution Piping.

lime is slaked in a continuous rotating drum type slaker. Ammonium sulphate is dissolved in lead-lined vortex bowls and activated carbon is mixed with water in a cast iron vortex bowl.

The alum solution is conveyed in lead-lined troughs and pipes to the raw water conduits in the sub-basement of the Chemical House. To the same point the lime suspension is conveyed in steel troughs and pipes. Ammonium sulphate is conveyed in lead-lined pipes to either the raw water tunnel or to the main effluent channel. The activated carbon suspension is conveyed through copper pipes to either the raw water conduits in the sub-basement or to the settled water conduits supplying the filters.

In the basement of the main building are the boiler room, battery room, oil room, and toilet rooms.

On the first floor of the two-story section of the building are chlorine scale rooms (Fig. 8) and chlorine storage rooms. On the second floor are chlorine control rooms (Fig. 9). From these rooms the chlorine solution piping leads to the raw water conduits in the sub-basement, to the main effluent channel, and to the shore shaft. Space has been provided for the expansion of the gaseous as well as the dry chemical feed facilities.

The following data and estimates were used in the design of chemical feed facilities of the plant.

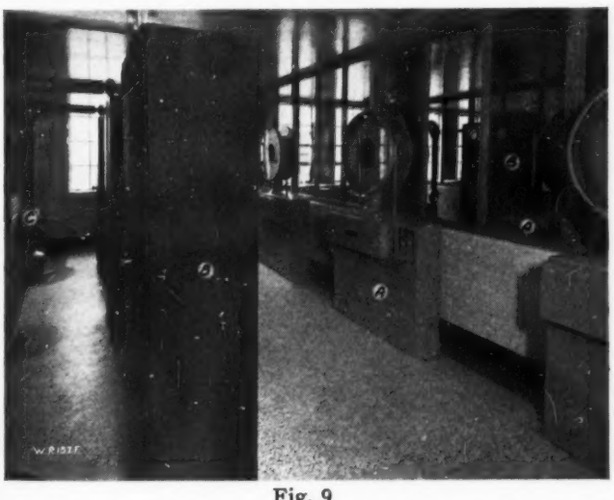


Fig. 9
Chlorine Control Rooms. (A) Scales; (B) Chlorinators; (C) Chlorine Solution Piping.

Alum

Feeders (Total)	3
Feeders in Reserve	1
One Feeder Will Feed	100 M.G.D.
Rates of Feed	0.6–1.9 G.P.G.
Rates of Feed (per Feeder)	1,720–12,750 lb/day
Capacity of Feeders Selected	480–36,000 lb/day

Lime

Feeders (Total)	1
Feeders in Reserve	0
One Feeder Will Feed	100 M.G.D.
Rates of Feed	0.24–1.4 G.P.G.
Rates of Feed (per Feeder)	1,750–30,000 lb/day
Capacity of Feeder Selected	480–36,000 lb/day

Carbon

Feeders (Total)	4
Machines in Reserve	1
Flow One Feeder Will Feed	100 M.G.D.
Rates of Feed	0.96–7.19 P.P.M.
Rates of Feed (per Feeder)	160–4,500 lb/day
Capacity of Feeder Selected	48–3,600 lb/day

Ammonium Sulphate

Feeders (Total)	3
Feeders in Reserve	1
Flow One Feeder Will Feed	200 M.G.D.
Rates of Feed (Pre. or Post)	0.12–2.24 P.P.M.
Rates of Feed per Feeder	50–1,500 lb/day
Capacity of Feeder Selected	48–3,600 lb/day

Chlorine

Number of Rooms	2
Chlorinators (Total)	6
Number in Reserve	3
Flow One Will Feed	100 M.G.D

	Pre.	*Post*
Rates of Feed (Lbs./M.G.)	2–10	1–2
Per Chlorinator (Lbs./M.G.)	40–715	50–286
Cap. of Chlorinators (Lbs./Day)	106–750	64–450

Chlorine Storage Capacity

Number of Containers (2,000 lbs. Cl. each)	52
Containers at Unloading Station	28
Containers in Plant	24

Bunker Storage Available

Alum—(13,300 cu. ft.)	399 tons
Lime—(13,300 cu. ft.)	399 tons
Ammonium Sulphate—(4,200 cu. ft.)	136 tons
Activated Carbon—(5,100 cu. ft.)	43 tons

Pneumatic Conveying Equipment
Capacity—7.5 tons per hour of dry granular Aluminum Sulphate weighing 55 to 60 lbs. per cu. ft.

Service Building

The Service Building (127×54 ft. floor area) contains an unloading room where lime and alum, delivered in bulk, are discharged from the service trucks into bins below the floor. A circulating air cleaning system removes the dusty air from the bins and returns the clean air to the unloading room above. Space for temporary bag storage of chemicals is also provided on the main floor with ready access to the elevator in the Chemical Building. There is also a machine shop, fully equipped, a garage and a store room for equipment used in maintaining the grounds. A second floor covers all but the garage part of the building and is used for storing miscellaneous equipment. The several entrances to the Service Building are off the south court between the Service and the Filter Building.

Coagulation Basins and Flocculators

The coagulation basins are of the double-deck type, each 372 feet long, 297 feet wide and 28 feet high, with the mixing and flocculating chambers at the inlet ends occupying 75 feet of the length, and the sedimentation basin the remainder. Each coagulation basin is divided by a solid partition wall extending the full length so that actually there are four coagulation basins. This

arrangement together with the locations of the raw water conduits and the settled water conduits permits the use of any combination of the four units.

The fall of the inlet side of the mixing chamber is located about 22 feet from the foundation wall of the Filter Building and Clear Well, and the space between the walls provides room for a gallery which connects with the east and west pipe galleries in the Filter Building. (Fig. 10.) It also provides space for a concrete raw water conduit 7 feet wide and 8 feet high inside and a concrete wash water drain 7 feet wide and 4 feet high inside. The raw water conduit is directly above the wash water drain and both are alongside of the mixing chamber with the inlet wall of the latter forming one side wall of the conduit and drain. The concrete raw water conduit connects with the 84" steel conduit from the pumping station at the west end of the gallery. Both the raw water conduit and the wash water drain extend the full width of the coagulation basin, the former in anticipation of its extension easterly when the plant is enlarged, and the latter to conduct the wash water, from the drains at the rear of each row of filters, out into the lake.

On the inside of the mixing-flocculating chamber, adjacent to the inlet wall of the basin and on top of the bottom floor slab, there is a diffusion chamber which is 7 feet wide and 6 feet 10 inches high and extends the full width of the flocculating basins. (Fig. 11.) Feeder slots 7 feet 3 inches long and 3 inches wide are located in the top slab of the diffusion chamber with the slots sloped up and back, at a 45 degree angle, toward the inlet wall of the chamber. Raw water passes from the raw water conduit into the diffusion chambers through 5 by 5-foot openings. Then by means of the feeder slots, the water passes from the diffusion chamber into the mixing chamber with an upward motion and back toward the inlet wall of the basin, thus starting the water through with a rotary motion, upward and toward the mechanical flocculator paddles.

Two rows of mechanically driven paddle wheels, rotating about a horizontal shaft, and two wooden baffles extending down from the ceiling of the mixing chamber, to within 3 feet of its floor, provide the necessary mixing and floc building. The first baffle is located 37.5 feet from the inlet wall and the second baffle 37.5 feet from the first baffle. One row of paddle wheels is located 22.5 feet from the inlet wall, and the second row is 30 feet from the first.

Double-Deck Design Economical

The double-deck type of coagulation basin was selected because it provides double the settling capacity for a given ground area involved and, too, because it was also possible to place the bottom of the coagulation basins

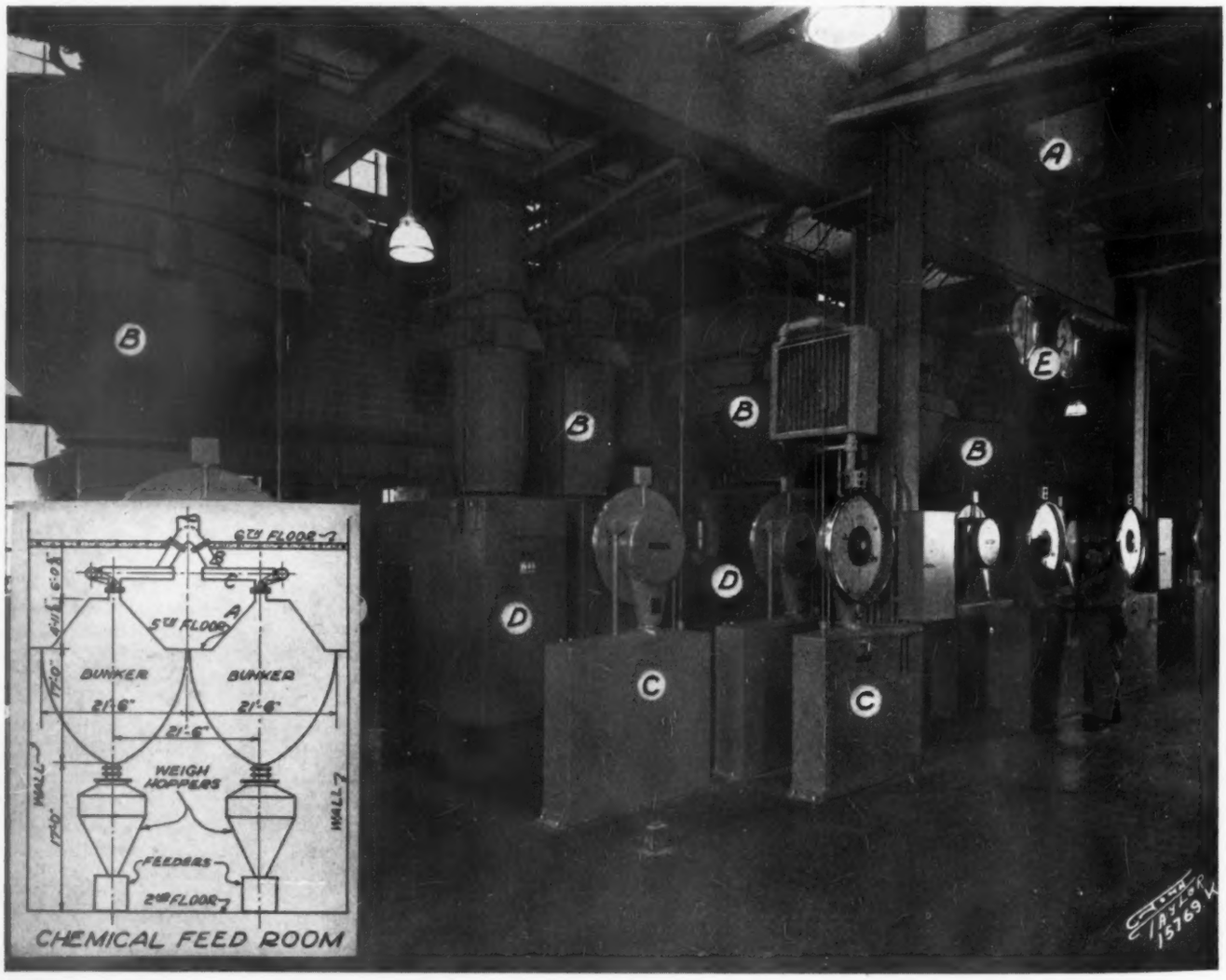


Fig. 7

Chemical Dry Feeder Room. (A) Storage Bunkers (above); (B) Weigh Hoppers; (C) Scales; (D) Enclosed electrically operated Continuous Feeders; (E) Raw Water Flow Indicators. (The inset sketch reveals size and location of Storage Bunkers above two rows of feeders. In this section only one row shows.)

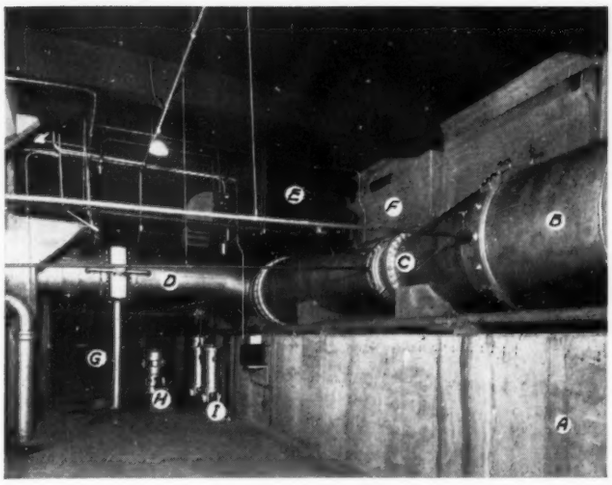


Fig. 10—South Pipe Gallery Looking East

(A) Concrete Raw Water Conduit; (B) 60-inch Steel Wash Water Line with (C) Venturi Meter; (D) 36-inch Wash Water Header to Filters; (E) Settled Water Conduit from (F) Coagulation Basin; (G) Wash Water Down Duct; (H) Coagulation Drainage Pumps; (I) Sluice Gates.

at the same elevation as the bottom of the clear well below the filters. The lower and upper decks are about 13 feet 5 inches deep. On leaving the flocculating chamber, the water travels along the lower deck to the far end of the basin, then up through openings in the middle slab to the upper deck where it flows back toward the inlet of the basin and to the settled water conduits. The openings in the middle slab are 5 by 4 feet, spaced 17 feet and located 5 feet 3 inches from the end wall of the basin.

The settled water conduits supplying the filters can be considered in two sections, one which collects the settled water in the coagulation basin, and the other which conducts the water to the filters. The settled water conduit in the coagulation basin is located under the top slab directly over the outlet end of the mixing chamber and extends the full width of the chamber (Fig. 11). It is 5 feet wide and 5 feet 8 inches high with slots 7 feet 3 inches long and 4 inches wide, spaced at 8 feet 6 inches, and about 2 feet 10 inches above the bottom of the conduit on the sedimentation side. This conduit is connected at right angles, at the mid-point in each half of the coagulation basin, to a conduit 10 feet wide and 4 feet 8 inches high, which extends along the center line of the pipe gallery straight through to the coagulation basin on the other side of the Filter Building.

To facilitate cleaning and flushing of the sedimentation basins, the bottom floor slab pitches toward a center gutter which connects with a conduit under the floor of the mixing chamber. The conduit leads to a drainage pump pit in the gallery from whence the washings are lifted into the wash water drain.

The following was used in the design of the coagulation basins:

Mixing-Flocculating Chambers (Covered)	
Number of Chambers	4
Time of mixing at nominal rating (min.)	60
Velocity at nominal rating (ft./min.)	1.16
Length of Travel (feet)	74
Head Loss in Mixing	0
Sedimentation Basins (Covered)	
Number of Basins	4*
Time of Coagulation and Settling (hours)	4
Velocity at nominal capacity (ft./min.)	2.32
Settled Water Conduits	
Velocity in Settled Water Conduit (ft./sec.)	1.8
Velocity in Filter Inlets (ft./sec.)	1.37

(*Each Unit—length 594'; width 148'; depth 13.5' contents 11.mg.)

(To be continued)

(Without materially cutting Mr. Schwada's very complete article, and dropping several attractive and informative pictures of plant units and structures, it proved impossible to run his valued contribution in this single issue. In the next and concluding installment of 6 pages Mr. Schwada's well ordered article continues with "The Filter Building" and what it houses, through to the high service pumps. We greatly regret that we could not displace other planned material for this special issue, in order that the complete Milwaukee article of 15 pages could be run in a single issue. Mr. Schwada's next installment is filled with interesting aspects of the filter plant proper and operation control features.—Editor.)

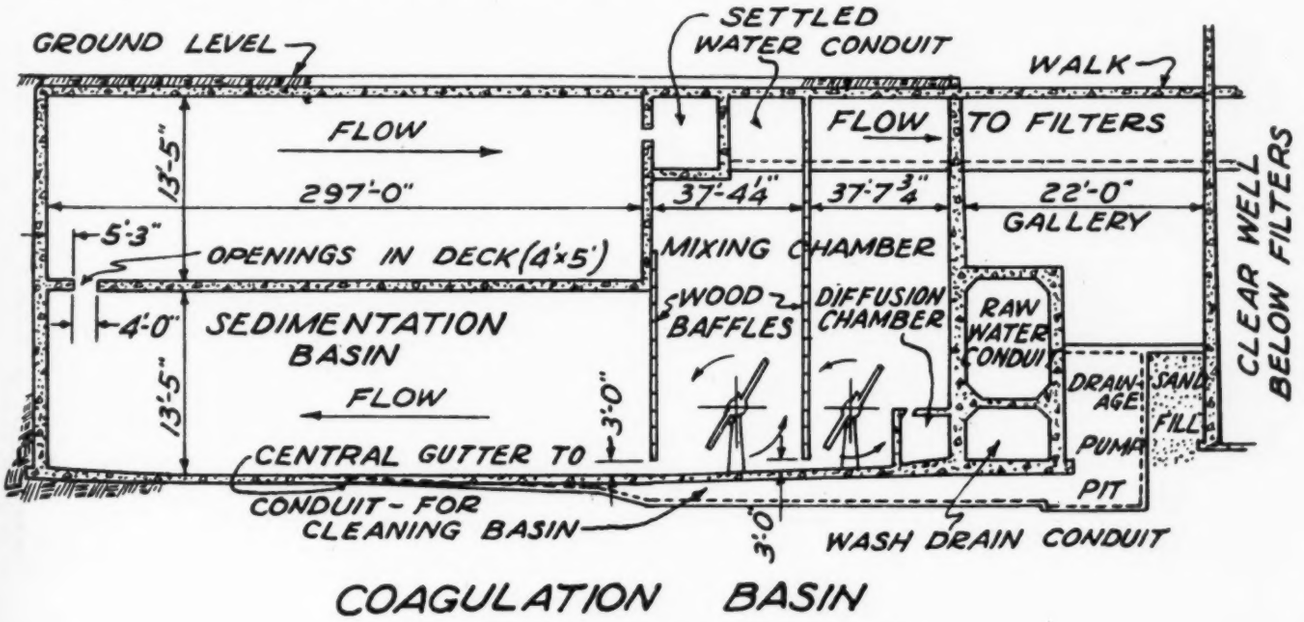


Fig. 11—Mixing Chamber and Coagulating Basin

Note Concrete Diffusion Chamber with Slots and Paddle Wheel Flocculators.

"SUPER–SUPER" CHLORINATION
AN EXPERIENCE

Process Put to Real Test at Unheard of Dosages at Ottumwa

By HORACE A. BROWN
Superintendent of Water
OTTUMWA, IOWA

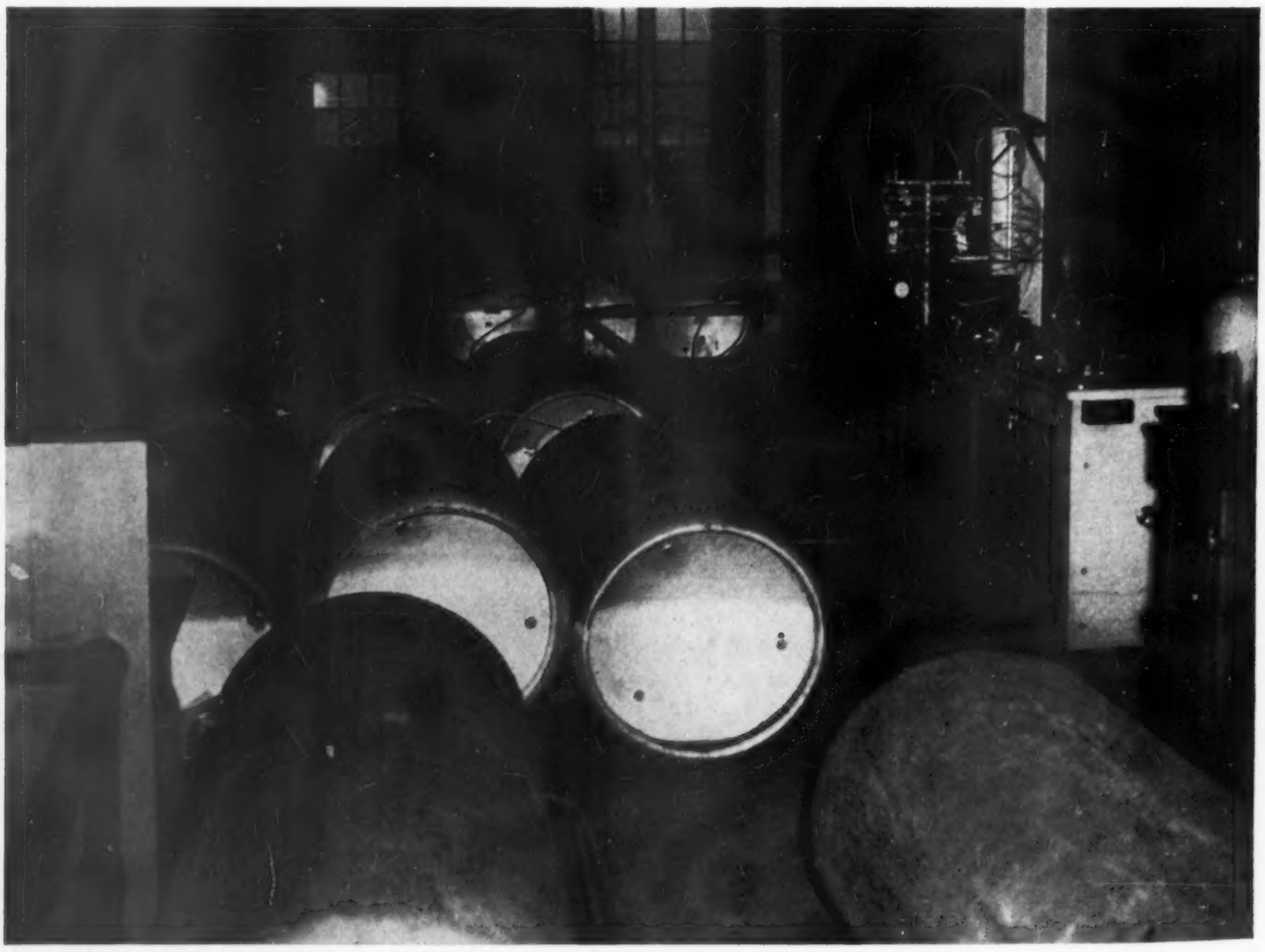
OUR city, Ottumwa, Ia. (estimated population of 35,000 for the 1940 census) is located on the Des Moines River 107 miles, via river, below the sewer outlets of our capital city, Des Moines, which has an estimated population for 1940 census of 140,000.

Located in Des Moines is a fair-sized meat packing plant, one or more rendering plants and numerous other industries, the wastes from which together with all of the domestic sewage of the city are discharged directly into the river, without treatment of any kind. Ottumwa is the only city below Des Moines that takes its water supply directly from the river.

The Author

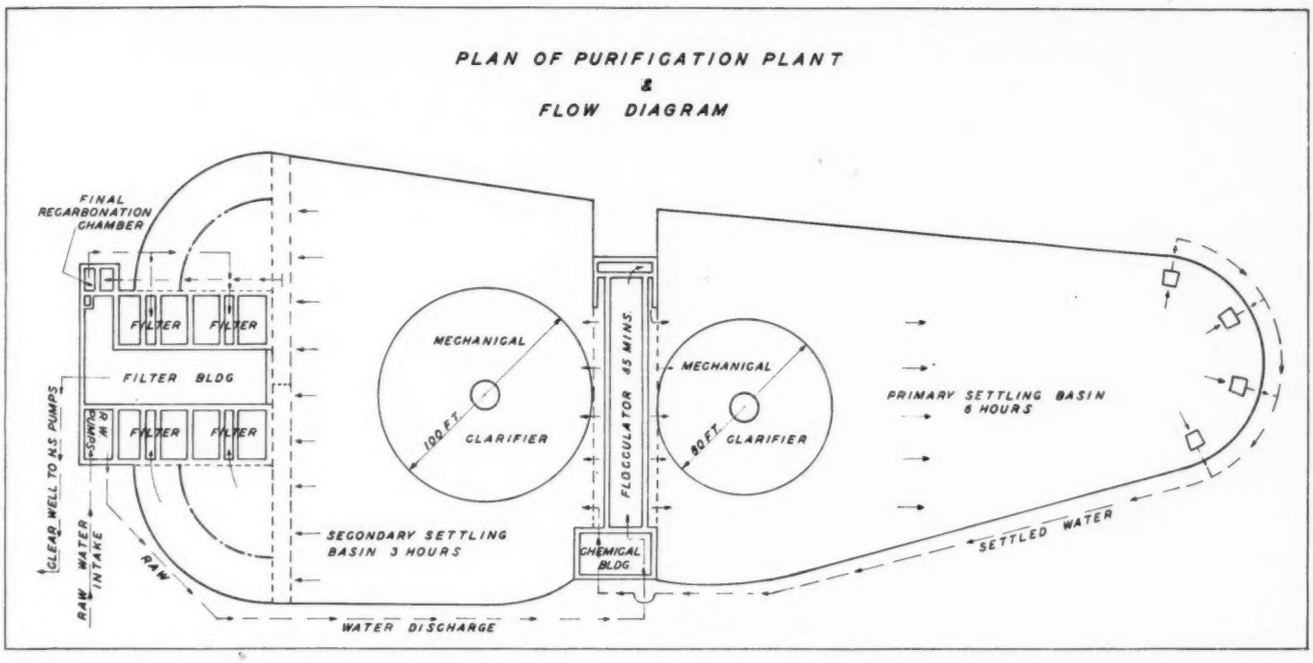
This last fall and winter found our river at a record-making low flow, the total volume coming into Des Moines was 18 million gallons per day, (U. S. Geological Survey records), of which the Des Moines water works was pumping 6 million gallons per day onto the sand fields below which their infiltration galleries are located. The total amount of water being used in Des Moines was about 14 million gallons per day, the bulk of which was being returned to the river as raw sewage. This gave a total river flow leaving the city of 26 million gallons per day (14 sewage, +12 natural flow) of which more than 50% was the city's and industry's sewage.

Our winter really started the 26th day of December, at which time our raw water at Ottumwa was carrying between 15 and 16 p.p.m. of dis-



Containers to the Right of Us; Containers to the Left of Us!

To feed 112 ppm. of chlorine (almost 8,000 lbs./day) we had to keep hooking on more and more ton containers. In the end we had 12 units in service. The 10 valve feed-control manifold, which we assembled, appears beyond the operating table. Note also our shop made flexible tank connections made from copper service-tubing.



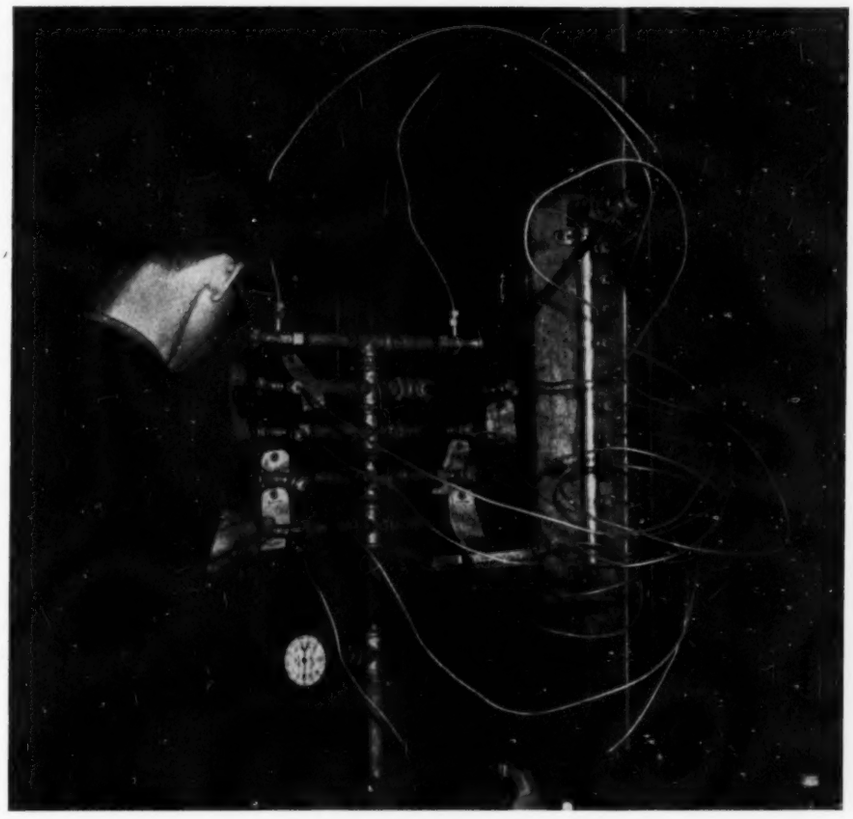
General Plan of the Softening and Filtration Plant of Ottumwa, Ia.

solved oxygen and 10 to 12 p.p.m. of CO_2. The river became frozen over with a heavy ice seal, 15 to 18 inches thick, and by the morning of January 19th the dissolved oxygen had dropped to a trace, and disappeared entirely at times during the day. The turbidity at that time was 30 p.p.m., the thick ice cap, covered by a blanket of snow, had formed a completely closed conduit leading directly from the Des Moines sewers to our intake. [Thus, the river became little other than a sealed sewage conduit 107 miles in length—a septic tank, if you can think of such a thing as a source of a community's water supply. That it was even more than that appears in the next paragraph—a combination of septic tank and a fish-pound—Ed.]

Simultaneously with the disappearance of dissolved oxygen from the raw water, dead and dying fish began to appear in our intake in large numbers, several truck loads per day being thrown out. Bad tastes and odors rapidly developed, and a real battle was on to produce a wholesome and palatable product from such a water.

Heavy Pre-Chlorination and Carbon Fail

Our first attempt at solution of the problem was pre-chlorination applying one (1) p.p.m. of chlorine, which was the maximum that our chlorinator could normally handle, followed by increasingly large doses of activated carbon. This treatment relieved the situation for a day or so, but did not effect a cure, we wired the Wallace & Tiernan Co. for larger equipment. Pending the arrival of such we made certain changes in our equipment, whereby we were enabled to feed 3 p.p.m. of chlorine into the suction of our raw water pumps. Again a short period of relief, but the raw water tastes and odors were daily growing stronger and accomplishments proved only temporary.



The Emergency Control Manifold

With the ¼ in. "jumper" valve open wide, control was secured by adjustment of 10 W. & T. auxiliary tank valves. The chlorine gas was conducted, as such, to the 16 in. pump suction line through W. & T. rubber hose. Surprising to us, the pump showed no signs of attack by the chlorine gas.

Super-Chlorination Tried

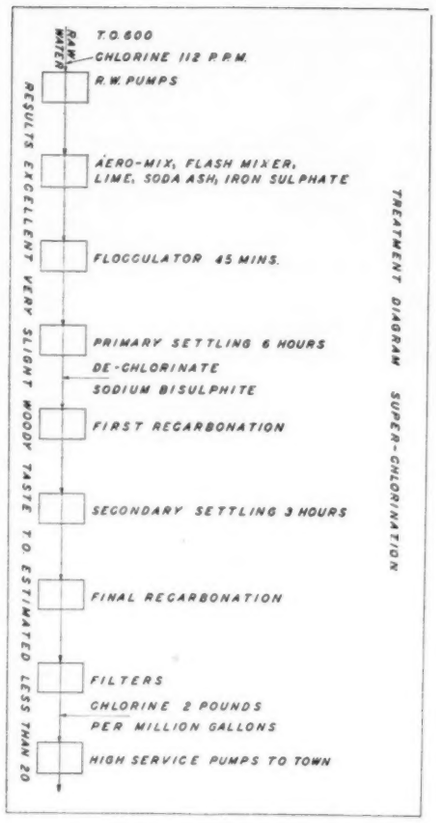
On February 4th we received, by fast express, from Wallace & Tiernan Co. a new vacuum type chlorinator having a maximum capacity of 720 lbs. of chlorine per day. At our rate of pumpage, (8 m.g.d) the machine enabled us to feed an additional 10.6 p.p.m. of chlorine, or a total of 13.6 p.p.m. which we hoped would prove an effective super-chlorination dosage. We first applied this additional 10.6 p.p.m. of chlorine at the entrance to our secondary basin, (see plan) and discontinued the use of activated carbon. After a three-day trial at this point we changed the point of application to the treated water entering the flocculator, (our softening treatment then consisting of 20 g.p.g. of lime and 6 g.p.g. of soda ash), thereafter de-chlorinating the filtered water, containing roughly 4 p.p.m. residual, with sodium bisulphite solution fed by one of the "Little Red Pumps" of % Proportioneers, Inc. %.

Apparent Failure

The results from this treatment proved disappointing, about 40 to 50 Threshold Odor in the finished water being the result. However, it is pertinent to note that the raw water at this time was coming to us with a Threshold Odor of about 600, as determined by tests run by Messrs. Poston and Bennett, engineers from the State Board of Health, who had remained with us ever since the trouble became severe.

Our next move was to change the point of de-chlorination to the outlet of the primary settling basin and to resume the application of activated carbon at the entrance to the first re-carbonation basin, doses of carbon were rapidly increased until 400 lbs. per million gallons was being applied. We immediately were plagued with carbon coming through the filters, we effectively stopped this by adding 1 g.p.g. of alum in the final re-carbonation basin, which served as an excellent flash mixer. This gave us a good floc with which to trap the carbon and to keep it from penetrating the filter beds. The results were still poor, we were not able to reduce the T. O. value below 30 in the filtered water. We then changed the location of the new chlorinator so that all of the chlorine, 13.6 p.p.m., could be applied to the suction of the raw water pumps, leaving the rest of the treatment as before, only a very slight benefit therefrom was noticeable as the result of this scheme to secure a longer chlorine contact period.

The citizens of Ottumwa had by this time practically abandoned our water for cooking and drinking. It had a terrible odor such as one observes around dirty urinals — stale urine and ammonia combined.



The Flow Sheet

Steps in the Treatment as it Finally Worked Out

Through the newspapers we kept the public fully informed as to the reason for the trouble and the efforts being made to remedy the same. The citizens proved very considerate in recognizing our dilemma and our long hours of battling the trouble.

The De-Chlorinating Unit

One of the Proportioneers' "Little Red Pumps", and a stand-by electrically operated gasoline engine fuel pump (on left) did Yeoman's duty. With this set up we could easily feed 65 pounds of sodium bi-sulphite per hour.

Desperation Brought Us to "Super"-Experimentation

On Sunday, February 25th, Mr. Elliott, our laboratory technician, and the writer started some tests to find out at what chlorine dosage the so-called chlorination "Breaking Point," if any, would be found in our water.

We set up a series of 16 jars into each of which we put 500 ml. of raw water, and applied doses of chlorine beginning at two (2) p.p.pm. and increasing in each successive jar by two (2) p.p.m. so that the jars of treated water carried 2-4-6-8-10 etc. p.p.m of applied chlorine, allowed the treated samples to stand 30 minutes, then drew off 50 m.l. of the treated water into small flasks and determined the residual chlorine by the starch-iodide method of titrating with sodium thiosulphate. The jars were then dumped and the process repeated, beginning where the last series left off. We kept this up all day when at about 6:00 P.M. we noticed

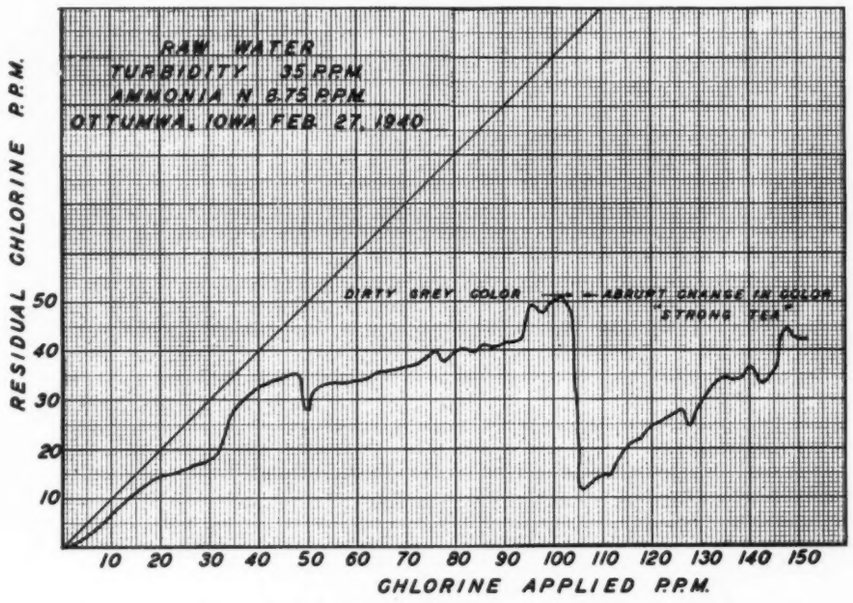


Fig. 1—The Super-Chlorination "Breaking-Point" Picture of Feb. 27th

Note the sudden "break" at dosage of 106 *ppm. when the residual precipitately dropped from* 51 *down to* 11.5 *ppm. Earlier the "break" had taken place with a dosage increase of only* 2 *ppm. i.e. between* 110 *and* 112 *ppm.*

that the very last jar of the last series had taken on a radically different color. *This jar had been treated with* 112 *p.p.m. of chlorine.* We rushed through with the titration and found that this specimen showed a chlorine residual of only 9.1 p.p.m. while the water in the next jar, treated with 110 p.p.m., yielded 41.4 p.p.m. residual chlorine. *We had found the "Breaking Point"!* This discovery seemed too spectacular to accept on a single test. Think of it—a sharp disappearance ("break") of 32.3 p.p.m of residual at the critical point of 112 p.p.m. dosage

And Are Rewarded

The next morning we started a new series of tests, beginning however with 96 p.p.m. and going on up in increments of 2 p.p.m. as before. This time we found the "Breaking Point" to be at 106 p.p.m. At this dosage the final residual was 11.5 p.p.m., whereas the sample treated with 104 p.p.m. (only 2 p.p.m. less) yielded a residual of 47.7 p.p.m. We continued this series of tests on out to 152 p.p.m. in order to ascertain whether or not another "Break" might appear. The accompanying graph (Fig. 1) shows the complete record plotted for this series of trials. We then set up 3 two-liter samples on our laboratory stirrer and applied 100—106—116 p.p.m. of chlorine respectively, stirred vigorously, added 20 g.p.g. of lime and 7 g.p.g. of soda ash, stirred slowly for 45 minutes, filtered, de-chlorinated, and tested. Results: 100 *p.p.m. very poor,* (strong urine and ammonia), 106 *and* 116 *p.p.m. excellent,* only a very, very slight woody taste. Now, we felt that we could exclaim—"EUREKA!" We did not consider it worth the effort to determine the Threshold Odor number but it was in our opinion not more than 2. (If we say 4, we would be ultra-conservative.) In either event, the result was startlingly excellent.

Our next problem was how to apply such a terrific dose of chlorine. While the stiring machine was operating, in what proved the conclusive test, the writer was making sketches of emergency apparatus to handle the enormous dose of almost 1,000 lbs. per million— truly unparalleled in water treatment, as far as we have been able to determine. The result was the equipment shown in the accompanying photographs.

Emergency Set-Up

We first connected 4 one-ton chlorine containers to a ¾" galvanized iron pipe, which led to the 10 connection chlorine manifold through the 10 auxiliary tank valves shown, the plan being to regulate the flow of chlorine by the number of auxiliary tank valves that were opened. Within 1 hour after starting up we found that 4 one-ton containers were not enough as they were rapidly frosting and pressures dropping fast. About ⅛ inch of frost formed over the entire tanks, and the pressure dropped from 40 lbs. to 10 lbs. per sq. in. We were not then getting enough chlorine to reach the "breaking-point."

We stopped the plant and rolled in 4 more one-ton containers. From a ½ inch water meter connections and 4 foot-lengths of soft drawn copper tubing, with iron pipe terminals soldered thereto, we made perfect flexible tank connections. In a relatively short time we were again ready to start up. But, again the tanks began to frost and the pressure dropped until not enough chlorine could be fed.

So, 4 more ton-containers were rolled in and connected up in the same manner, making a total of 12 one-ton containers now connected to the ¾ inch pipe leading to our improvised control manifold. This time the tanks did not lose too much pressure, but we then found that we could not get enough gas through the 10 small valves and pipes to reach the desired quantity of 106 to 116 p.p.m., involving 960 lbs. per m.g. × 8 m.g.d. = 7,680 lbs./day. The next step was to cut in a ¼ inch "jumper" line with valve from the ¾ inch supply header to the 1 inch hose outlet. (See photograph.) At last we had enough capacity and everything clicked, by now it was time to shut down the plant. Our system has enough storage so that the purification plant normally operates only 10 to 12 hours per day.

We Now Were Ready for Real Super-Chlorination

On Wednesday morning, February 28th, we started off with real super-chlorination at a dosage of 112 p.p.m. That quick decisive change in color (possibly not duplicated in other waters) gave our operators a clear-cut indication of when they had applied sufficient chlorine. All of the chlorine applied was going in as gaseous chlorine through a 1 inch silver tube, projecting into the 16 inch suction line to our centrifugal raw water pump. One minute later samples were taken at the chemical house in order to check the amount of residual chlorine in the water entering the flash-mixer. At the start off, with the 12 one-ton containers giving 30 lbs. pressure at the control manifold, we needed the ¼ inch jumper valve wide open and 8 of the ten auxiliary tank valves on the manifold open to get the required amount of chlorine.

Interesting Observations

In running the various tests we noted the following interesting phenomena: Our raw water, carrying a

light grey turbidity of 30 to 50, when chlorinated to, or beyond, the "Breaking Point" turns a decidedly strong tea color which grew stronger upon standing. Then, in a short time, a floc formed. In about two hours this floc bore a close resemblance to clotted blood, both in color and appearance, and we estimated that 90% of this floc settled and 10% floated. Upon careful de-chlorination with sodium bisulphite, involving a short quick stirring, the red color quickly disappeared, except a very few of the red particles of floating floc. The settled floc apparently re-dissolved and the water became clear, except for a very light pin point floc, which quickly started forming.

Treating this sample with 16 g.p.g. of lime created a very heavy floc, which *floated* 100%—a strange effect for lime to produce. Repeated breaking up with stirring rod (8 to 10 times) finally caused about 90% of the floc to settle and remain on the bottom. Upon filtering and warming to 70° F. This precipitate had only a very slight woody taste, not at all objectionable.

Another sample of the super-chlorinated water was de-chlorinated immediately before the color change had time to take place. Treated with the same amount of lime, (16 g.p.g.), the floc was not nearly as heavy as before and it all settled to the bottom of the jar and stayed there; upon filtering and warming to 70° F. only the same slight woody taste could be detected. This observation indicated that odor and taste-distinction, in our severe case, was not improved by a delay to allow the color to form or the chlorine to act during long contact periods.

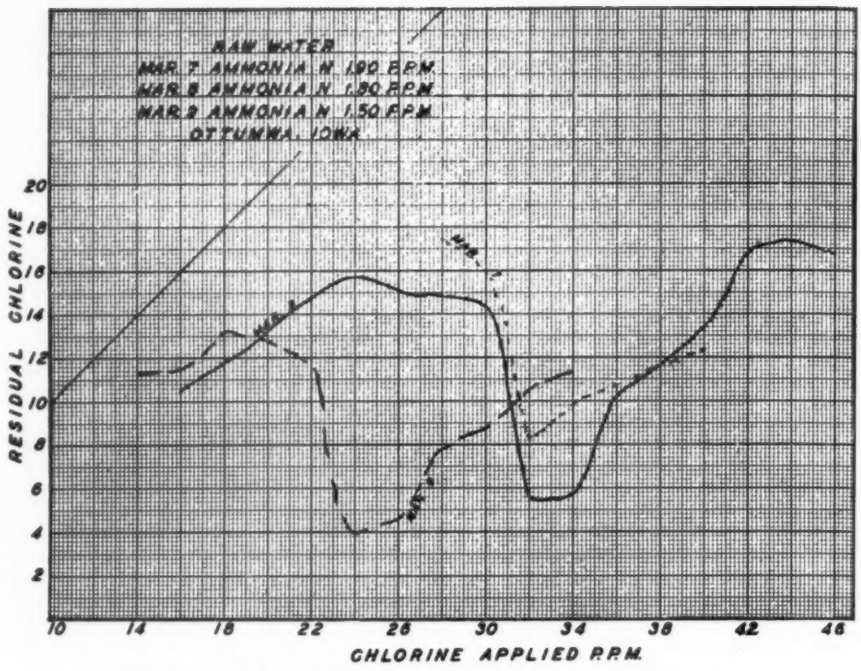


Fig. 3—"Breaking-Points" as Observed on March 7, 8 and 9
Note the gradual recession of these points with the improving condition of the river.

A Look at What We Were Treating

As an indication of the kind of water we were handling we have obtained from the State Board of Health engineers their record of the B.O.D. values (a test commonly applied to sewage and sewage effluent) of samples taken directly in front of our intake. The tabulation follows:

Day	B.O.D. (p.p.m.)
Jan. 12	7.3
" 22	*15.0
" 23	*12.0
" 24	18.0
" 25	28.0
" 26	28.0
Feb. 1	41.0
" 6	45.0

* Strength of effluent from a sewage treatment plant of the activated sludge type.

No such determinations were made after February 6th, it is however our opinion that materially higher B.O.D.s were encountered later in February, possibly as high as 60 to 70.

Bacterial counts, made in our laboratory, were as follows:

Date	Litmus Lactose Agar (24 hours at 37° C)	Plain Nutrient Agar (48 hours at 20° C)
Jan. 12	160	1,200
" 22	220	6,400
" 24	430	3,520
" 25	70	2,800
" 31	1,100	18,200
Feb. 1	400	9,200
" 7	21,600	38,900
" 14	4,800	12,800
" 25	26,400	30,400
" 28	12,800	34,400
Mar. 2	23,200	35,200
" 6	30,000	520,000
" 9	3,000	124,000
" 13	1,800	12,400

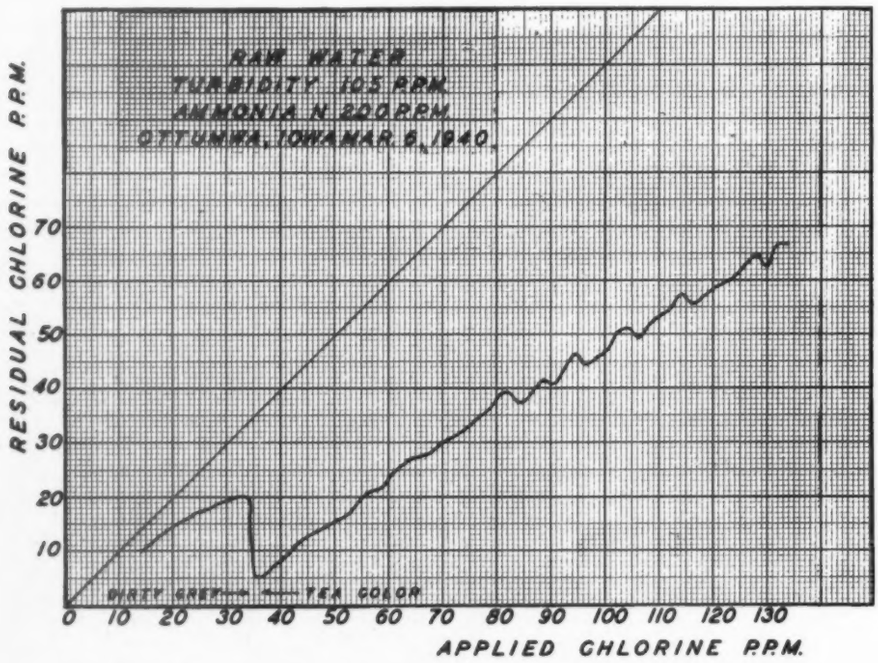


Fig. 2—The "Breaking-Point" Picture on March 6th Had Changed
Note the less pronounced "break" and the much lower dosage involved. The sanitary analysis indicates the improving water quality.

Sanitary analyses made at the State Hygenic Laboratory at Iowa City, from samples collected by Messrs. Poston and Bennett, revealed the following:

Date Collected		
Feb. 24	RAW	Ammonia N. 8.75—Albuminoid N. 1.35—Organic N. 2.70 Nitrite N. 0.010—Nitrate N. 0.30 Chloride 60.0—Manganese 6.4
	TAP	Ammonia N. 540—Albuminoid N. 0.80—Organic N. 1.80 Nitrite N. 0.013—Nitrate N. 0.1—Chloride 68. Manganese, Trace
Feb. 29	RAW	Ammonia N. 9.4—Albuminoid N. 1.9—Organic N. 3.4 Nitrite N. .005—Nitrate N. 0.8—Chloride 62.0
	TAP	Ammonia N. 8.25—Albuminoid N. 1.1—Organic N. 1.6 Nitrite N. .015—Nitrate N. 0.4—Chloride (Cl) 72.0
Mar. 6	RAW	Ammonia N. 3.60—Albuminoid N. 0.56—Organic N. 3.9 Nitrite N. 0.015—Nitrate N. 0.4—Manganese 2.0
	TAP	Ammonia N. 0.96—Albuminoid N. 0.20—Organic N. 1.0 Nitrite N. 0.175—Nitrate N. 0.2—Manganese 0.0

The samples taken on February 29th and March 6th are the only ones taken after super-chlorination started. [With considerable interest it is noted that, whereas, more than 100 p.p.m. of chlorine were added only 10 p.p.m. could be found as the mineral chlorine increase—i.e. Raw 62, Treated 72.—Ed.]

We finally discontinued, what our local papers termed "Super-Colossal Chlorination" on March 18th as the river was rapidly opening up and substantially more water was flowing. We are now back to our regular method of operation.

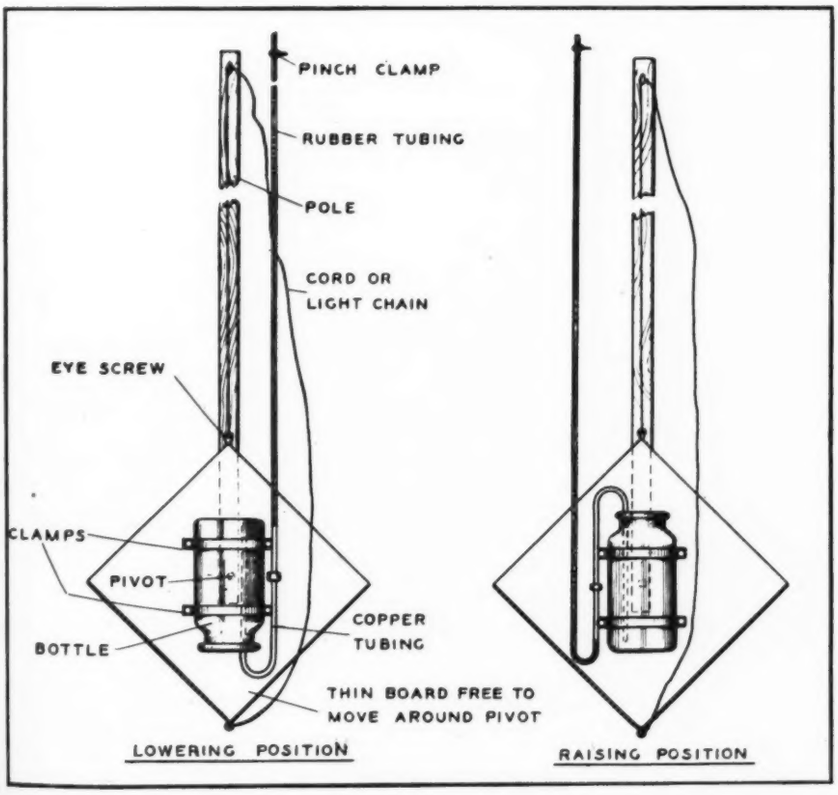
We were somewhat concerned about the possible condition of our raw water pump after handling such volumes of chlorine, we therefore removed the top half of the pump casing and were pleased (and admittedly somewhat surprised) to find that no evidence of damage was present. The inside of the pump casing as well as all rotating parts had a thin coating of scale which had accumulated during the seven years this pump had been in operation, handling a fairly hard raw water. This scale had apparently kept the chlorine from coming in contact with any of the metal. We also wonder how corrosive the apparent excess of residual chlorine really was in a water so highly charged with organic colloids as was that at Ottumwa during the super-chlorination period.

Our experience indicates that very heavily contaminated waters can be successfully handled by super-chlorination when conditions justify the usage of such super dosages as may be required to destroy tastes and odors.

"ACKNOWLEDGEMENT:

This device employed in studies made by the authors at Ypsilanti, Mich., was perfected by Mr. Geo. Darby, Director of the Westport Laboratories of the Dorr Company. It is a modification of a somewhat similar device earlier developed at the Howard Bend Purification Plant at St. Louis, Mo."

Apparatus For Collecting Flocculated Samples*



The apparatus shown on the accompanying sketch consists of a wide mouth bottle clamped to a thin board, which in turn is attached to a pole of suitable length. The board is free to rotate on the center pivot and may be turned by the string or light chain attached to the two opposite corners. The bottle may be vented through tubing which extends above the liquid surface.

When the bottle is lowered in inverted position, the pinch clamp on the vent line is closed. When the desired sampling level is reached, the pinch clamp is released, so that the floc containing liquid slowly enters the bottle as the air is released. When the bottle is full it is rotated and then raised to upright position with the pull chain.

Through use of this apparatus, flocculated samples from any liquid depth may be collected. The breaking up of flocs, such as occurs when samples are pumped or taken by means of a small mouthed bottle, is avoided.

*Contributed by A. J. Fischer and A. Hillman, The Dorr Co., New York City.

The Prize Exhibit

Link-Belt's complete working model of a high-rate high-capacity "Bio-filtration" plant, executed in remarkable detail and operating on recirculated water.

N.J. SILVER ANNIVERSARY CONVENTION

A Success in Every Direction

THE New Jersey Sewage Works Association some months ago set out to do something March 20th, 22nd—and, IT DID!

Readers of this magazine have noted in earlier issues reports of plans under way by America's oldest sewage works association to celebrate its 25th year by staging a Silver Anniversary Convention. There were certain predictions, based on advance indications, that the marks set by the Silver Anniversary Steering Committee would be reached. They were —*and more.*

It has never happened before, to this reporter's knowledge at least, that any association serving the sewerage field has ever had a convention of such proportions. The paid registration totalled 450—amongst which were names from Iowa, Kansas, Michigan, Ohio, Georgia, Canada, North Carolina, to add National flavor to the meeting. It has never happened before that a manufacturers' exhibit at a sewerage meeting has been of the size or quality which Trenton's War Memorial Building housed March 20-22nd—every available inch of space being taken by the 38 firms exhibiting. That the quality of the exhibit arrangements ranked with those of the American Water Works Association is evidenced in the pictures accompanying this report—although two of the most interesting exhibits located on the right and left below the camera fail to show.

The New President
Sam Probasco, City Engineer, Burlington, N. J.

General Chairman,
Silver Anniversary Conv.
Wm. J. Orchard, Maplewood, N. J.

We will not dwell on entertainment other than to agree with the many who felt that the opening "Get-Together" Smoker, the Big Show and Annual Dinner, and the novel "Last Round Up" at the close of the final technical session, constituted a big $3.00 worth, this figure being the full registration fee.

Presidents

(1915) *John R. Downes, Supt. Treatment Works Plainfield, N. J.*

(1940) *Edw. P. Molitor, Supt. Treatment Works Chatham-Madison, N. J.*

At this point we want to digress for a minute to say that those who are familiar with the sort of job that "Bill" Orchard has done in handling convention arrangements and entertainment for A.W.W.A., will understand what we mean when we say that the N. J. Silver Anniversary Convention was a typical "Orchard Show," only on a smaller scale than those of A.W.W.A.,—and, when we say "Orchard Show" we are not referring to the exhibition of "peaches" on Thursday night. Then, too, "Bill" knew his men when he picked Charlie Becker to take charge of Exhibits and Joe Wafer (both with A.W.W.A. Convention experience) to assist P. N. Daniels, (long *the* N. J. Committee on Local Arrangements), with entertainment. So, this is by way of saying "a big hand to all four." And, hats off to Harry Croft, Chairman of the Program Committee, and Paul Molitor, Jr., and Tony Anable for the splendid job on Publicity and Attendance.

It was a bang-up Convention and everything clicked straight through from opening to closing.

The Governor Adds Much

It is not frequent that a State water or sewage works association rates a Governor's presence. And, still less frequent that a Governor has water supply and stream pollution as much at heart as has the Governor of New Jersey. As ample evidence of this we recall the fact that Governor Harry Moore came to Atlantic City last year to address A.W.W.A. Last year he appeared for a few minutes at the meeting of the N. J. Sewage Works Association. This time he was on hand for the opening luncheon, to start the Convention wheels rolling with an address ringing such praise in the ears of sewage works men as to make each feel that he was doing things for the State and humanity that could but yield greater rewards than measured in compensation alone. The Governor did not come just to give his listeners a glad-hand speech and retire. Instead, he came prepared to comment on the work of "America's Heros in Sanitation" and to recommend the recent book "Death Loses

1st Vice President
Henry Van der Vleit
Supt. Public Works Maywood, N. J.

2nd Vice President
John W. Collom, City Engineer, Bordentown, N. J.

New Jersey's First Family—The Molitors
(All being Superintendents—retired or active)
Flanked by his two "boys" is an illustrious Father

Paul Molitor I—a revered charter member, the association's second president, and at present a membe rof its Executive Committee. On his right is "Ed.", who has just completed a two-year term as President. On his left is Paul II, the association's capable Treasurer and Asst. Secretary. At home was Paul III, and we wonder if he, too, will "carry on." Incidentally, Paul I can boast an 100% attendance score, not having missed any of the 25 meetings since 1915.

It's Wings" which is something of a history of outstanding accomplishments that have made this world a safer place in which to live. And, so, may we add a "big-hand" for New Jersey's Governor. This is superfluous, however, because he certainly got just that.

Following the Governor, Dr. J. Lynn Mahaffey, Director of the N. J. State Dep't. of Health, traced the parallel history of the disappearance of the so-called waterborne diseases with the growth of water and sewage treatment, and the N. J. Sewage Works Ass'n., which he had been informed had since its inception been headed only by actual sewage works operators and run for the benefit of operators.

Probably in no other State is the President of the State Board of Health a Sanitary Engineer. Such is the case in New Jersey and, later in the meeting, the President of the Board, Clyde Potts, Consulting Engineer and long the Mayor of Morristown, presented an impressive review of the work and accomplishments of the Engineering Division of the State Dep't. of Health since its establishment.

Charter Members Honored

The opening luncheon served as an occasion to pay tribute to twenty-six charter members of the Association, six of whom are still active members and answered "Here" when the roll was called by the first President—John R. Downes. Thereafter, Mr. Downes, in reminiscing, took a look back at what there was in the way of sewage treatment in 1915 when the Association was organized, in comparison with what it is today. He cited the fact that he then could name the dozen trained operators in charge of treatment plants in the Country as a whole. He remarked the fact that at that time the chief role of the State Sanitary Engineer group (then irreverently referred to as the "State House Boys") was that of sanitation policemen, snooping, sleuthing and reporting; whereas, today these individuals had come to be the operators' most helpful friends. Much of this development of cooperative spirit and helpful endeavor could be credited to the N. J. Association, said Downes.

A Visitor of Distinction

Amongst those in attendance was a visitor of distinction from abroad—Dr. George Ornstein of Berlin, Germany. Dr. Ornstein was introduced to the Association, by Linn H. Enslow, as "The Father of Solution Feed Chlorination," for the reason that the Doctor developed the process of adding chlorine gas in water solution here in America in 1912, while in the employ of the Electro Bleaching Gas Co. For this novel development patents, now famous as the Ornstein (Solution Feed) patents, were granted him. His first solution feed chlorinator was installed on the Niagara Falls supply and the second at Wilmington, Del. The chlorinator business of the E. B. G. Co. was later taken over by Messrs. Wallace & Tiernan, along with all patent rights, and Dr. Ornstein returned to Germany to exploit his patents and market chlorinators abroad, and now on a visit to America to marvel at what has come of the beginnings in Niagara Falls, in 1912.

Dr. Ornstein, in perfect English, spoke briefly concerning his early endeavors and showed lantern slides picturing his first and second successful solution feed chlorinators, which made an interesting comparison with the giant 6,000-pound a day machines in the sewage plants of Buffalo and Detroit.

Dr. Ornstein also had a slide of the very first cylinder of liquid chlorine produced in America, in which E. B. G. Co. were the pioneers.

Wolman Paper Highlight

Amongst the several excellent papers presented in the Technical Sessions, that by Dr. Abel Wolman of

A Governor Starts The Wheels Rolling

The Governor of New Jersey, A. Harry Moore, had more to say than his audience had anticipated.

Johns Hopkins University was outstanding. His paper, "The Construction of Sewage Treatment Works and Its Relation to the National Economy" is of such immediate interest to so many that we are making an effort to print it in full in this same issue—if unsuccessful, then in our May issue.

Gas Hazards Report Adopted

Following a discussion of the "Report of the Committee on Gas Hazards at Sewage Treatment Plants" this worthy effort in the direction of safety to sewage works operators was by resolution accepted and adopted as the official operating guide for all sewage treatment plants in New Jersey.

Concerning Part 2, that dealing with design, the resolution carried a request to the State Dep't. of Health that this section of the report be adopted as a part of its policy in the examination and approval of plans and engineering data submitted in connection with the design of sewage plants and sewer systems.

The first draft of this valuable report was read before the Association a year ago and discussed. Since then it has been freely distributed for the purpose of soliciting opinions, looking to justified revisions and possible improvements. The final draft, as now approved, constitutes the best available known guide in the design and operation of gas collection, gas handling, and gas utilization equipment at sewage works. In view of the wide-spread need for such a guide, this report on Gas Hazards, and means of correction, is being printed in full in a prominent position in the Reference and Data Section of this issue.

Orchard Proves the "Master Salesman"

In a carefully thought out and effectively prepared speech, W. J. Orchard made an impressive and a fruitful plea for prompt action in the direction of establishing a National Sewage Works Association. He cited the need for a centralized headquarters office, a paid Executive Secretary and necessary staff to render the type of service to sewage works men in this Country, such as has been so successfully done by the American Water Works Association for water works men. He painted the picture of the present sectional and state associations comprising the loosely bound Federation of Sewage Works Associations, as having served a most useful purpose but having produced much less of inter-association (nationwide) value than would have been, and can in the future be, the case with an energizing and coordinating central office and committees of national scope at work on the many problems of sewerage construction and plant operation. Concerning such potentialities, he cited much that has been done by the A.W.W.A. in the water supply field with an organization of the character proposed, and made up of many regional Sections functioning as units.

The Director of Health
Dr. J. L. Mahaffey
Trenton, N. J.

President of the Board
Clyde Potts, C.E.
Morristown, N. J.

Following Orchard's thorough and impressive plea for coordination and concentration of effort and interests, he asked for a voice of opinion and reaction to his arguments from the Federation's Chairman, C. A. Emerson and the several representatives of various Federation associations present in the room.

At this point, Mr. Emerson assumed direction of the discussion. The general thought of those who voiced opinions was that there *is* a need for a National Association, one set up on its own without affiliation with, or dependence on, any existing association. Further, that the present member associations of the Federation should not be disturbed in any Nationalization move, since they could well function and conduct

Silver Anniversary Celebration of the N. J. Sewage Works Association—The Banquet Attendance was 327

their business in a manner similar to that under which the several Sections of A.W.W.A. operate so successfully. Under these conditions, hearing nothing but a favorable voice, Mr. Emerson recited the fact that the Federation Committee on Reorganization has recommended to the Board of Control essentially all that had been expressed in the discussion and at present the committee was studying the necessary revisions to the Constitution and By-laws of the Federation to make such a change permissive. Moreover, the Board of Control had voted to hold a Convention of National Scope at a central point this coming Fall—ample proof of the fact that Orchard had more thoroughly sold his ideas, first voiced about a year ago to the Federation Board, than may have been generally realized.

The New Jersey Association has never been a member of the Federation and it then fell to Orchard to use an opportune moment to sell its members on the idea that their Association could strengthen the general movement considerably by taking a part in the proposed National Association. Here is where he did a masterful selling job, resulting in a resolution recommending favorable consideration and empowering the Executive Committee of the Association to take proper action, should the proposal of a National Association become an actuality within the year. This resolution carried without a dissenting voice.

Federation Board Takes Prompt Action

Having heard nothing but favorable reaction to the proposed move to effect a closer knit Federation, Chairman Emerson called a special meeting of all Board of Control members and representatives of the various Federation units in attendance. In this meeting it was voted to hold the proposed National Sewage Works Convention this fall in Chicago, preferably (and practically with certainty) in conjunction with the annual meeting of the Central States Association.

It was then voted to request the Water Works Mfgrs. Assn. to arrange for an Equipment Exhibit in conjunction therewith, similar to the very effective exhibit at Trenton. Toward this end, Orchard was requested to act for the Federation. During the Chicago Convention actions will be taken on the proposals and recommendations of the Committee on Reorganization and Nationalization, with the thought that the close of 1940 will see an American Sewage Works Association actually in motion.

America's Biggest Showing of Sewerage Equipment—With 38 Firms Exhibiting
(Disappointed applicants lamented the fact that they had procrastinated)

Exhibitors

Activated Alum Corp.
American Brass Co.
American City Magazine.
Builders Iron Foundry.
Ralph B. Carter Co.
Chain Belt Co.
Chicago Pump Co.
DeLaval Steam Turbine Co.
The Dorr Co., Inc.
Engineering News-Record.
Fairbanks, Morse & Co.
Industrial Chemical Sales.
Inertol Co., Inc.
Johns-Manville.
Laughlin Equipment Corp.

Link-Belt Co.
James Maskell.
Mathieson Alkali Works.
Mine Safety Appliance Co.
Municipal Sanitation.
Pacific Flush Tank Co.
Pardee Engineering Co.
Penna. Salt Mfg. Co.
Pittsburgh Equit. Meter Co.
Jos. G. Pollard Co., Inc.
Public Works.
Signal Engineering Co.
Tapax Mfg. Co., Inc.
Arthur H. Thomas Co.
U. S. Pipe & Fdry. Co.
Vapor Recovery Systems Co.
Wailes Dove, Hermiston Corp.
Wallace & Tiernan Co.
Walker Bros.
R. D. Wood Co.
Water Works & Sewerage.
Yeomans Bros. Co.

(As commentary, it was interesting to note that some representatives attending from other Associations expressed disappointment that they could not return with a report that a National Association had actually been launched at the Trenton meeting.)

Officers Elected

In the New Jersey Association officers are elected on alternate years for two year terms. This was an election year, and the following constitute the officers for the next two years.

President, Samuel R. Probasco, Sup't. Burlington, N. J.

1st Vice-Pres., Henry Van der Vleit, Sup't., Maywood, N. J.

2nd Vice-Pres., John Collom, Sup't., Bordentown, N. J.

Secretary, John R. Downes, Sup't., Plainfield, N. J.

Treasurer, Paul Molitor, Jr., Sup't., Morristown, N. J.

Technical Sessions

(Reported by Harry A. Faber, Assoc. Editor.)

"Sewage Treatment Practices in Foreign Lands" by FRANK BACHMAN, Sanitary Sales Director, The Dorr Co., New York, N. Y.

From his travels abroad, of general interest because of the itinerary and of specific appeal to this audience because of the sewage treatment practices observed, Mr. Bachman returned with photographs of many treatment plants. Showing these as lantern slides, he conducted the audience over the same tour—describing the significant and amusing features of each visit.

A review can but mention a few of the high points in such a paper. Beginning in England, he touched on unusual types of trickling filters equipped with rotary distributors; the Mogden activated sludge plant—world's largest until completion of the Southwest Chicago plant; cracking of sewage with sulfuric acid for recovery of wool grease at Birmingham, Bradford, and Halifax; together with pictures which graphically illustrated cleaning of sedimentation tanks—manually, since the majority of English settling tanks are not mechanically equipped.

Charlie Emerson, Consulting Engr., N. Y. City (called together his Federation Board, on the spot, to decide that there would be a National Sewerage Convention this Fall in Chicago). George Gascoigne, Consulting Engr., Cleveland, O. (came to read a paper on Sludge Incineration)

On the continent, an experimental activated sludge plant near Paris is of 52 m.g.d. capacity and will eventually be over ten times that size. In Holland novel types of aerators, a treatment plant in the center of town, and the application of digested sludge directly to land proved of outstanding interest. Necessity for fuel in Germany has led to mixing of digested sludge with peat for use as fuel. Italy has its first mechanized activated sludge sewage treatment plant at Trieste.

The warmer countries have serious disposal problems. Colombo is the largest city of Celon and the only one having a sewage disposal system (Imhoff tanks). Because of hookworm, so universally prevalent, sludge cannot be used as fertilizer. In India every large city has its water supply but, as consumption averages only 25 Imperial gals. per capita per day, the sewage is extremely strong. While treatment is relatively rare, inland cities are forbidden from discharging sewage into streams; disposal by irrigation is most popular.

Disinfection of lettuce grown in sewage irrigated soil, by means of permanganate, is generally practiced but did not appear very effective to Mr. Bachman. The city of Lohore has a population of three to four hundred thousand, but no sewer system. Both Bombay and Bengal have mechanical type activated sludge treatment plants, while many cities have only septic tanks. Because the temperature in India is about 80° F. the year around, sludge digestion is quite rapid.

It was apparent that in England and on the Continent, operators possessed high technical ability; other countries of the East are anxious to learn. Such sewage works associations as exist in the United States would be of great value to more rapid progress in the countries less advanced.

Cleveland's Coterie

All the way from Cleveland, Ohio, came George Flower, Supt., Southerly Treatment Works; W. F. Schade, Chief Chemist, Easterly Works; J. J. Wirtz, Supt., Easterly Works; C. B. Budd, Chief Operator, Southerly Works.

"Some Observations on Trickling Filters" by MAX LEVINE, Professor, Dept. of Bacteriology, Iowa State College, and Bacteriologist, Engineering Experiment Station, Ames, Iowa.

Postulating that we have not yet fully realized the possibilties of trick-

Speakers

(1) *Frank Bachmann, Manager Sanitary Engineering Div., The Dorr Co., N. Y. City;* (2) *Abel Wolman (Dr. Eng.) Head of Dept. of Sanitary Engineering Johns Hopkins Univ., Baltimore, Md.;* (3) *F. W. Mohlman, (Ph.D.), Chief Chemist, The Sanitary Distr. of Chicago, and Editor of Sewage Works Journal;* (4) *Max Levine (Ph.D.), Head, Dept. Bacteriology, Iowa State College, Ames, Ia.;* (5) *R. S. Phillips, Supt. Water Purification and Sewage Treatment, Durham, North Carolina;* (6) *Paul Hansen, Greeley & Hansen, Engrs., Chicago.*

ling filters as a method of sewage and industrial waste treatment, Prof. Levine said that this method of treatment has survived because it is gradually becoming better understood. While the limitations of activated sludge treatment have been made apparent in handling industrial wastes, the more rugged trickling filter has proven to be not upset by sudden changes in concentration or quality of wastes.

It is also significant that a highly nitrified effluent was considered essential 25 years ago, while today effluent of low oxygen demand rather than high stability is the desired attainment. This point is important in the return of the trickling filter to favor. Activated sludge treatment proving not well adapted, concentrated wastes have been effectively handled at high rates of filtration.

The results of studies show adequate ventilation of such filters to be essential: Without ventilation high ammonia, high B.O.D., and less ni-

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trification are typical of the effluent. Clogging was especially prevalent when ventilation was not provided, both with wastes high in carbohydrates and with those high in protein. Maximum purification efficiency was obtained with a short dosing cycle (about 3 minutes) and the filter effected an aglomeration of solids at high dosing rates. Subsequent settling of filter effluent showed an 80% B.O.D. removal when high rates were used, as against a 20% removal only, when using low rates.

Such a filter acts, in Prof. Levine's opinion, as both a physical-chemical colloider (actually, he pointed out, more properly as a de-colloider) and, in addition, as a biological transformer. Sewage, in passing downward through the filter, is continuously modified by the changing microbial populations which exist in integrating zones. Only at the bottom of filters do nitryifying and sulphur-oxidizing types of bacteria exist.

Actual plant operation has demonstrated that on concentrated wastes filter efficiency and capacity can be tremendously increased through provision of declogable primary filters. In a plant consisting of a primary clarifier, primary filter (shallow and equipped for backwashing like a water filter), intermediate clarifier, secondary high rate filter, and final

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clarifier, an overall removal of 94% has been demonstrated. At such a plant in West Fargo, N. D. primary flocculation without chemicals is also included, resulting in 65% removals from packing waste after the first filtration and over 90% removal after the second filters.

Lively discussion was provoked by this highly interesting paper. *Linn H. Enslow*, terming high rate filtration results revolutionary, suggested the possibilities of high rate strainers (such as magnetite filters) for removal of fine colloidal matter following filtration at high rates. *Frank Bachman* noted that just such a plant is now being built at Liberty, N. Y., where a high rate filter effluent will be "polished" by means of a magne-

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tite filter. In reply to a question, *Prof. Levine* said that below a 2 minute cycle the law of diminishing returns becomes significant and that a continuous dosing shows little improvement. In regard to maximum loading, 16 m.g.a.d. of 220 B.O.D. waste can be adequately treated.

Weston Gavett, noted that a magnetite filter is used for effluent polishing at Englewood, N. J., and asked whether or not forced draft aeration is required for ordinary trickling filters. *Prof. Levine* doubts the necessity for aeration unless ventilation is not adequate.

Morris Cohn mentioned the high B.O.D. removals and high nitrification obtained at the Schenectady, N. Y. plant despite the fact that filter bottoms are submerged 85% of the time.

"The Construction of a Sewage Treatment Plant Under the Provisions of Section 40: 1-79 of the Revised Statutes of New Jersey (Sewer Rentals)" by R. C. HENDRICKSON, City Attorney, Vice-Chairman Interstate Commission on the Delaware River Basin, and State Senator, Woodbury, N. J.

The New Jersey law which enables construction of a sewage treatment plant on a self-liquidating basis

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was described in detail by Mr. Hendrickson. Under this law, the City of Woodbury has nearly completed construction of a sewage treatment plant and other improvements to its sewer system. The city has a population of 10,000 owns its water supply which is 100% metered (3,033 meters), and has 2,368 sewer connections within the city. The collecting sewer system is old, subject to considerable infiltration; the Imhoff treatment plant is inadequate; the city has been served notice by the State Dept. of Health to construct a new sewage disposal plant.

The new treatment plant is of modern Imhoff type, with primary and secondary sedimentation with chlorination. Total cost of plant and improvements is $165,000, which is funded over a 25-year period. Sewer rental charges are set up as follows: For each building connected, $8.00 per annum plus one-third of the actual water bill; for factories, etc. $1.00 for each employee—for the

first year, thereafter a flat charge of $35.00 per year; sewer connections outside city limits, a flat charge of $15.00 per year. Sewer rental will be payable quarterly (and billed with water charges) in advance. Unpaid bill will constitute a lien on property. Charges have intentionally been made high for the first year, but the rate schedule has been made flexible and subsequent reduction is expected.

"The Construction of a Sewerage System or Sewage Treatment Plant Under the Provisions of Sub-division (g), Section 40: 1-16 of the Revised Statutes (An Order of Necessity)" by S. A. KOWALCHIK, Senior Sanitary Engineer, State Department of Health, Trenton, N. J.

The provisions of this law, which enables any municipality of the State to make improvements required by the courts, even if the municipality has already reached its maximum indebtedness, were described in detail. A city may be required to com-

Exhibits and Entertainment
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(Chairman of Committee on Exhibits)
P. N. Daniels, Sanitary Engr.
(Chairman of Committee on Arrangements)
Joe Wafer, Ind. Chem. Sales Co.
(Vice-Chm'n, Committee on Entertainment)

ply with an order of the State Department of Health if a menace to public health exists—issuance of a cease and desist notice constituting sufficient evidence of the need for improvements. Application of the law hinges on the question "will cost of the improvements increase debt of the municipality beyond the maximum 7% limit?".

The Department of Health recognizes its responsibility for requiring improvements when excess debt of a municipality is above statutory limitations, but it is required to protect the health of the State's inhabitants. So far the Department has issued 47 orders for the construction of sewage treatment works (totaling $11,500,000 in cost). The period of most construction occurred in 1938 when P.W.A. grants were available, and has since dwindled. It appears that some enabling legislation is needed, but the outlook for this is not too promising. The Health Department may issue an "Order of Necessity" and it is probable that intensification of their efforts will be required to accomplish necessary improvements.

"Development and Utilization of Power from Sewage Gas at Durham, N. C." by R. S. PHILLIPS, Chief Chemist, Department of Water and Sewers, Durham, N. C.

Among the first cities to install gas engines for utilization of power from digested sludge, the Durham sewage treatment plant has also been most progressive in recovery and utilization of waste heat from this gas. The Northside plant of the city treats approximately 3.3 m.g.d or about 65% of the total sewage flow. Because sewage received at this plant contains about 0.5 m.g.d. of wastes from dyeing and bleaching, in addition to usual domestic and industrial wastes, the population equivalent is almost 60,000 instead of an estimated connected population of 350,000.

Primary and activated sludge are digested in three digestion tanks, each of 60,000 cu. ft. capacity, and equipped with floating covers. Ten sludge drying beds (four under glass) provide about 0.84 sq. ft. drying area per capita. These are insufficient to handle the digested sludge, which contains only 6% solids, and several large lagoons have been added to dispose of sludge.

The theoretical digestion period is 50 days, temperature is maintained at 82° F. volatile matter is reduced from 61% to 38%, and about 46,000 cu. ft. of gas is produced daily (6,049 B.T.U.'s per pound of volatile matter added). A study made by the author and the plant chemist showed that Kier liquor could be digested with an 80-90% reduction in oxygen requirements of the digested liquor, while resulting in production of an estimated 13,000 cu. ft. of gas per 25,000 gal. of Kier liquor received daily. Accordingly it is proposed to pipe this troublesome liquor separately into the plant for digestion, thus reducing air requirements and raising the amount of power generated.

The two Cooper-Bessemer 150 h.p. gas engines are directly connected to 2400 volt generators. A sub-station, with high voltage transformers provides for interchange of power with the city's hydro-electric plant and the local power company. This permits operation of the gas engines at full load at all times and makes for most efficient operation. A gas colorimeter continuously recording quality of the sludge gas from each digester; addition of lime to digesters is based on this data, and (despite the presence of industrial wastes) foaming never occurs. This accounts, in part, for the high quality of sludge gas—700 B.T.U. per cu. ft. Each engine operates about one-half of the total time hence necessary adjustments can be made without interruptions. An average of one kilowatt hour is generated per 19.8 cu. ft. of gas, giving an overall efficiency of 27.5%.

Recovery of waste heat from the engines is by means of a completely closed system using city water. This heat may be used for temperature control of the digesters, for heating sludge on drying beds, or entirely wasted through a heat-exchanger submerged in one of the aeration units. Excess heat, beyond that required to heat the well-insulated digesters, is available at all times and has been used for one year to speed the drying of sludge in the four covered sludge drying beds. Heating coils, laid just below the sand sur-

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face, have been so effective that a 43% in crease in solids removal per unit bed area was made possible.

In the conclusion of his most competently prepared and presented paper, Mr. Phillips gave the total operating and treatment costs for a four-year period as: averaging $15.01 per m.g. sewage treated or $7.09 per 1,000 pounds of B.O.D. removed, indicated in a degree of the value of power production with gas engines.

"The Installation and Operation of a Small Dairy Waste Treatment Plant" by C. M. NICHOLS, Senior Sanitary Engr., State Dept. of Health, Trenton, N. J.

Because of the many potable water supplies, for which streams of this State must be the source, New Jersey restricts the discharge of untreated industrial waste into its waters. While regulating the degree of treatment required, the State Dept. of Health does not specify how the waste is to be treated. The milk waste

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problem is particularly serious, because an estimated 1.15 million quarts of milk are produced daily and the processing of this in creameries creates numerous pollutions problems.

Treatment methods for such wastes include septic tanks, Imhoff plants, chemical coagulation, and trickling filters. Study of local problems to accomplish decrease of wastes to a minimum has been of material assistance. Mr. Nichols described in detail methods of conservation employed and pointed out the advantage of segregating cooling and other only slightly polluted waters.

The operation and results of one plant, employing chemical coagulation and disinfection, was described in detail. Twin settling tanks, each of sufficient capacity to retain the flow of waste for one day, are provided. The dose of alum varies from 25 to 35 grains per gallon; the dose of chlorine is adequate to give 2 to 3 p.p.m. residual. After chemical mixing a settling period of about 5 hours is provided, then the effluent is discharged at a low rate of flow while the second tank is fiilling. Sludge is disposed of on cinder filters. The chlorine dose both prevents sludge septicity and delays decomposition of effluent in the receiving stream.

Construction of a typical plant of this type was described by means of slides, and data on actual reductions accomplished was presented. Motion pictures depicting the various stages in milk processing, the sources of wastes, and operation of several treatment plants concluded the description.

"Construction of Sewage Treatment Works and Its Relation to the National Economy" by ABEL WOLMAN, Professor of Sanitary Engineering, Johns Hopkins University, Baltimore, Md.

In his usual competent fashion, Dr. Wolman described the varied and complex experiences in works construction during the past ten years, for the purpose of determining prospects of the future. The economic history of the United States, he noted, in 100 years (the period from 1840 to 1940) presents certain general indications on which to base predictions. Depressions have generally followed wars, either here or abroad; there have been at least ten major depressions, and periods of recovery are usually over 10 years in length. These have been accompanied by periods of liquidation, irrespective of political parties in power, for which no solution appears to have been found.

This country has great capacity for future industry: With only 7% of the world's population, it possesses over 40% of the national wealth. Important is the fact that, in 1938, Federal, State, and local expenditures totaled over 14 billion dollars. The interchange of tax funds before reaching sewage treatment works is even more complicated today than in the past. The total value of public and private construction in 1939 was about 10 billion dollars.

It is significant that the trend of general construction has moved uniformly upward (until 1932) regardless of other changes. Increases in population growth, standards of living, national income, and in construction of sewage treatment works have all paralleled this steady rise. In 1930 it was clearly shown by Mr. Leo Wolman that permanent improvements were falling behind in public works construction. This has not been corrected to date and the construction needs of the next 5 years are, consequently, at least as great as those of the late 1920's.

Several factors must be considered in considering possible decrease in population growth: Enrollment has decreased, in grade schools, by one million; but the registration in high schools has increased by 2.5 millions. While there are declines in growth of the New England and Middle Atlantic States, the South and Mid-West show increases in birth rates. Such changes in population growth and in birth rates mean changes in construction probabilities.

A careful survey has shown that, within the next ten years construction of sewage works (exclusive of sewers and laterals) may require the expenditure of approximately one billion dollars. In Baltimore, Md., for example, a population of 75 to 100,000 is not yet served by sewers; treatment works are needed to clean up streams; some ten million dollars of construction work is now needed. Baltimore is only typical of needs in large cities throughout the country: the same needs are apparent in cities such as New York, Los Angeles, Detroit, Boston, and Pittsburgh among others.

Also, according to this conservative estimate, another one billion dollars measures the needs of the next 10 years for construction in the industrial waste treatment field. In addition, there will be more reasons for sewage and waste treatment than are apparent today: for example, research may indicate the necessity of destroying the virus of poliomyelitis in sewage.

More satisfactory programing of future construction will be required —there not being twelve cities in the United States which have the semblance of an advance program for sewer or sewage treatment plant construction and an analysis of future needs. One barrier to future construction has been the error of financing bond issues over too long a period. Half a dozen states already have laws which prevent issuance of bonds, for public works construction, which are funded for more than forty years.

Mr. Wolman recommended extensive "professional thinking" as necessary in connection with new administrative devices, and believes that the amount of new construction will depend on proper organization. Such facilities as those provided by the

Interstate Commission on the Delaware River Basin (INCODEL) provide an example for future progress. Policies of stream cleanliness should require that at least 200 million dollars be expended yearly for sewage works during the next ten to twenty years.

(Mr. Wolman is Chairman of the Water Resources Committee of the National Resources Committee.—Ed.)

"Disposal of Sewage Sludge at Cleveland, Ohio" by GEORGE B. GASCOIGNE, Gascoigne and Associates, Cleveland, Ohio, and New York, N. Y.

Disposal of sewage sludge, according to Mr. Gascoigne, has been and still is the weakest link in sewage treatment. At Cleveland over twenty-five years of experiment and study have been devoted to this problem, with the result that today two vacuum filtration and incineration plants are in operation. These plants are located at the Southerly and Westerly treatment works, activated and raw sludge from the Easterly plant being pumped 13 miles for disposal at the Southerly works.

Cleveland has already favored digestion, in conjunction with incineration, because of returns in gas and fertilizer. At both Southerly and Westerly works, the digested sludge is conditioned with lime and ferric chloride, prior to vacuum filtration. Pebble lime and tank cars of liquid ferric chloride are delivered on plant railroad sidings.

Labor is usually the largest single item of expense disposal of sludge by filtration and incineration, though the largest sludge load can be handled at the minimum cost. When a given plant reaches maximum capacity labor costs per unit volume may decrease to one-half of that found at lower than capacity operation. Operation difficulties have now been largely corrected by manufacturers of filtration and incineration devices.

The total operating cost for filtering and incinerating sludge (exclusive of fixed charges) were given by Mr. Gascoigne as: per ton of dry solids, Southerly plant, $10.19; Westerly plant, $14.02. These figures, however, are based on solids in the digested sludge and not on raw sewage solids. There are no objectionable odors incident to filtration or incineration. While such treatment is not cheap, it does constitute the most positive and reliable method of sludge disposal.

(1) D. C. Freas, Genl. Mgr., Atlantic City Sewerage Co., and Henry Armbrust, Proportioneers, Inc., and Builders Iron Fdy., Providence, R. I. (2) "Cy" Tygert, loaded down with papers in one hand and hugging a W. & T. bell jar, has the job of Editor of the N. J. S.W.A. Proceedings. (3) H. Gartman and Chas. E. Coleman, Engrs., De Laval Turbine and Pump Co., Trenton.

"Sewage Treatment at Buffalo, New York" by PAUL HANSEN, Greeley and Hansen, Hydraulic and Sanitary Engineers, Chicago, Ill.

Mr. Hansen made a graphic story of the difficulties encountered in getting the Buffalo plant under way: Great rapidity was necessary in the preparation of plans, contracts were let serially, and hurried action of the State Legislature was required to acquire title to Bird Island for the plant site. Construction costs were estimated at 13.95 million dollars and final costs proved to be 13.25 million.

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Edw. G. Hyland, Supt., Water and Sewerage, Moorestown, N. J. (Past-President of the Association and present Chairman of the N. J. Section of A.W.W.A.)
Chas. H. Capen, Engineer, North Jersey Distr. Water Supply, Wanaque

The plant was built to remove pollution from Delaware Park Lake, Buffalo River, Buffalo Harbor and particularly to reduce bacterial pollution of the Niagara River. The 14 miles of interceptor sewers were designed for population increase over 50 years, the treatment works for an increase over a 30-year period. In addition to solids removal, the treatment plant provides disinfection of effluent by chlorination—pre-chlorination being the method employed. Sludge solids are partially digested, dewatered on vacuum filters, given flash drying and blown into furnaces. Auxiliary fuel may be used, but only sludge gas is now required for incineration.

The Buffalo sewer authority early placed technically trained men in charge and a preliminary study of quality and strength of the sewage was most valuable. Average results for the first 18 months of operation show the suspended solids load received to be 0.32 lb. per capita per 24 hours; grit removed is 3.94 cu. ft. per m.g. (this has a relatively high content of volatile matter, 43%, which adds to its fuel value since both slude and grit are incinerated); gas collected is 0.69 cu. ft. per capita; and the chlorine demand is 0.0113 lb. per capita per 24 hours.

"Disposal of Sewage and Industrial Wastes at Chicago" by F. W. MOHLMAN, Director of Laboratories, Sanitary District of Chicago, Chicago, Ill.

History of the Sanitary District since 1900 is divided into two major eras, each covering a score of years: The dilution project, from 1900 to 1920, and the sewage treatment project, from 1920 to 1940. The dilution project required expenditure of 125 million dollars and the sewage treatment project 160 million dollars. The District has an area of 442 sq. miles, including a human population of 4.7 million plus industrial wastes equivalent to approximately 2.2 million population.

Prior to 1900 sewage and wastes were discharged into Lake Michigan, but with opening of the main channel, Jan. 2, 1900, sewage was diverted from the lake and discharged into Des Plaines River, which joins the Kankakee River to form the Illinois River. The dilution ratio of 3.33 cu. ft. per second per 1,000 population was soon found to be inadequate. Experiments were started in 1909 on the treatment of sewage, three small Imhoff-trickling filter plants were soon built, to be followed by the DesPlaines activated sludge plant in 1922 and the Calumet Imhoff plant in 1923. Sewage treatment was then planned on a large scale, activated sludge treatment was decided upon and the North Side Works was placed in operation in 1928.

Further reduction in diversion of water from Lake Michigan was then

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required. This has progressively decreased to only 1,500 c.f.s. in 1939 as compared with the 4,167 c.f.s. originally authorized. During this reduction, sewage treatment plants were built as rapidly as funds permitted, until the program now requires only more complete treatment at the West Side Works.

Experimental work at the North Side Works has included a considerable variety of studies: centrifuges, sludge dewatering, Laughlin filter, the original Guggenheim process, etc. Activated sludge sewage treatment at this plant (average 203 m.g.d.) in 1939 gave a 93% reduction in B.O.D. and a 92% reduction in suspended solids. Sludge, 20% primary and 80% activated, is pumped from this plant 17 miles to the Southwest Works for disposal.

Sewage received at the Calumet Treatment Works is weak, but contains a variety of industrial wastes. Particularly troublesome have been pickling liquors whose iron content has been deposited in the pores of the diffuser plates. At this plant B.O.D. was reduced 87% and suspended solids reduced 91% in 1939 when an average of 72 m.g.d. was treated by the activated sludge process.

The West Side Treatment Works consists of 108 Imhoff tanks which, in 1939, treated an average 238 m.g.d. sewage flow with a reduction of 54% in B.O.D. and of 57% in suspended solids. Digested settled sludge at this works is dried on 37 acres of sand beds. Many studies have been made to determine how best to extend the degree of removal of B.O.D. and solids. Experiments include Halvorson high-rate trickling filter; Jenks two-stage bio-filter; chemical precipitation; magnetite filters; short aeration period activated sludge; and the Guggenheim biochemical process. Short period activated sludge treatment has produced the superior effluent, accomplishing overall reduction of 90% when using aeration periods as low as 1.45 hours with 0.18 cu. ft. of air per gallon.

The Southwest Treatment Works was started in operation on June 9, 1939, hence variable results have been obtained while tuning up the plant. Results for January, 1940, show activated sludge treatment of an average 287 m.g.d. to have accomplished 91% B.O.D. and 93% suspended solids reductions. Most of the sludge produced has been sold as fertilizer.

Packinghouse and stockyard wastes create an outstanding problem among the industrial wastes in Chicago sewage, and are expected to impose a considerable burden on the Southwest Works where they will shortly be received. Other wastes of importance include those from tanneries and breweries.

As the great sewage treatment program of the District is fast approaching completion, the sanitary condition of the main channel and the Illinois River will be of great concern to the Sanitary District. A large volume of analytical data is continuously being collected and that for the summer of 1940 will be of particular interest, since the conditions below Chicago were the poorest in 1939 or any for many years. Present indications are that the 1,500 c.f.s. allowed as draft from Lake Michigan will have to be increased.

"Developments and Trends in Sewage Treatment" by LINN H. ENSLOW, Editor, WATER WORKS & SEWERAGE, New York City.

Mr. Enslow, with lantern slides, went back to the year of the organization of the New Jersey Association to show America's earliest Imhoff tanks, installed first at Madison-Chatham, N. J., and Atlanta, Ga., then the newest of styles in sewage treatment devices. Unfortunately, these and other early units persisted in working "upside-down", and supplied interesting and speculative discussion, as to the reasons for such behavior, for a number of years in the early history of "America's Pioneer Sewage Works Association" —and still interesting reading in the early issues of its Proceedings. Then he showed a slide of the first gas collecting system and gas holder—that at Atlanta, Ga., which supplied fuel for heat and cooking in the Chemist's Home, that of C. C. Hommon, a pioneer amongst trained sewage plant operators.

Then followed a scene of an early attempt at sludge and scum incineration at Dallas, Texas, which made an interesting comparison with the modern sludge incinerators of today, which have come through with much better than guaranteed performance both in work and economy in the modern large plants of today. Mr. Enslow showed a picture of the first centrifugal pump in the sanitation field. It happened to be a sewage pump located in Norfolk, Va. The entire unit could pass through the eye of one of the new giant centrifugals of the Sanitary District of Chicago.

Pushed for time on a program running considerably behind schedule, Mr. Enslow rather hurriedly covered only some of the more impressive recent developments in sewage treatment. In this, emphasis was placed on the come back of the trickling filter represented by the astounding performance of the recent high-rate, high-capacity installations and their especial interest in connection with treatment of strong industrial wastes, notably packinghouse wastes. Slides were shown of the two types of high-rate filters, one being equipped for back-washing with air and effluent when bed cloggage began to appear.

In connection with sewerage clarification the "Clari-Flocculator" had proved a highly interesting development since the flocculating unit, occupying space at the center of the circular tank, apparently took up no space of settling value in the clarifier and in producing mechanical flocculation in the stirring mechanism served also as a perfect preventor of tank short circuiting. Another feature was that chemicals could be added to increase removals by flocculation at will, and as conditions demanded. In industrial waste treatment much could be expected of such combination flocculation and clarifying units.

The benefits of aero-chlorination in degreasing sewages, particularly those receiving activated sludge treatment, were reviewed; and, also the

value of concentrating activated sludge to reduce liquor input into digesters, had been demonstrated as two worthwhile developments involving chlorine. Also, in this connection, the original Scott-Darcey process of combining chlorine and scrap iron would hardly be recognized in its present status of development giving high flexibility in chemical control for odors, flocculation and disinfection, as demonstrated in western plants.

Impressive results were being secured from continuously cleaned straining filters on effluents, particularly on chemical effluents and might be expected to prove their worth on high-rate trickling filter effluents which carried floc of low specific settling values. Probably many activated sludge plants could be more economically operated with such final strainers.

Mr. Enslow directed attention to the remarkable achievement in New Jersey in respect to cleaning up a complete river valley as a unit—namely the Raritan Valley program in which each polluter (industry and municipality) had been required simultaneously to effect that degree of purification indicated for the point of discharge. As a sound procedure in pollution abatement the Raritan Valley program had no equal in this Country. He also directed attention to the outstanding achievements in correction of industrial pollution in the Illinois River Valley, through quiet cooperative efforts between industry and the Illinois Sanitary Water Board.

"Twenty Five Years of Progress in Sanitation in New Jersey" by CLYDE POTTS, Consulting Engineer, New York City.

Mr. Potts, having served as the engineer-member of the N. J. State Board of Health since 1915 and now President of the Board, and as a charter member of the N. J. Sewage Works Association, came well qualified as a reviewer of progress and attainments in sanitation in New Jersey.

The beginnings date from 1899, when a Sewerage Commission was appointed to function under the State Board of Health. In 1915 a reorganization created the State Dep't. of Health, with a Division of Water and Sewage and a Bureau of Engineering. Of particular interest was the fact that the new regulations required that two members of the Board of Health be sanitary engineers, M. N. Baker and Mr. Potts being appointed. In 1918, three years after the reorganization and formation of the N. J. Sewage Works Ass'n., an operator licensing act was put through, the Board's reasoning being that water and sewage operators should rate with health-officers in the matter of proven qualifications and status.

In referring to historic attainments, Mr. Potts said that N. J. could well be proud of the part it played in making water treatment history, particularly the establishment of the worth of chlorination by adding bleaching powder to the Jersey City Supply in 1909, when the typhoid index of that community was 100. Thereafter, the conclusive demonstration of the efficacy of chlorination at Trenton two

(1) *Francis H. Friel, Cons. Engr., Philadelphia, and Harry M. Freeburn, Distr. Engr., Penna. Dept. of Health, Philadelphia*; (2) *E. A. Sigworth, Industrial Chem. Sales Div., N. Y. City; R. S. Phillips, Chief Chemist, Dept. of Water and Sewage, Durham, N. C.; Harry Krum, Supt. Filtration and Sewage Treatment, Allentown, Pa.*

years later (1911), up to which time raw Delaware River water constituted the supply. In 1914 the Trenton filter plant was built.

Further facts; in 1905 only 5% of N. J. surface supplies received treatment of any sort; by 1920 it was 70%; and since 1933—100%. In the State there are now 283 public water supplies. (Mr. Potts did not claim it, but we believe we are correct in saying that the earliest American mechanical "rapid-type" filter plant on a municipal supply was a New Jersey plant. Also, that earliest chlorination of sewage on a practical basis was in New Jersey, at Red Bank.—ED.)

Concerning growth of sewage treatment, New Jersey is exceeded only by Texas in the number of sewage treatment plants, which by 1938 had reached a total of 263. Mr. Potts was high in his praise of the Engineering Division for accomplishments in general and the particularly impressive recent demonstration of what can be attained in the direction of a clean-up of a complete drainage basin. He referred to the Raritan River Valley program involving revamping of old plants and construction of 11 new municipal treatment plants, to make the total number 21, and the 19 industrial waste plants in operation with 11 more under design or construction.

Plant Operation and Maintenance

(A Symposium)

"The Abatement of Odor Nuisance at Manasquam, N. J." by J. K. VAN BRUNT, Sup't. Water and Sewerage, Manasquam, N. J.

The sewage treatment plant of Manasquam, a seashore resort, is one of the several New Jersey coastal plants constructed wholly underground. This one is under a street with cottages and stores on either side. The settling tanks become septic between cleanings, and sea water infiltration has been responsible for considerable hydrogen sulphide production and odor complaint. Correctives for odor nuisances included installation of a comminutor to render screenings handling unnecessary. Prechlorination, under the circumstances, was not an effective remedy. A complete forced ventilating system was installed to draw in fresh purging air from the street level above and to discharge through a hollow steel flagpole 75 ft. high. The cast-bronze impeller 5 H.P. Buffalo Forge Co. blower is of a capacity to completely change the air in the underground space every 9½ minutes. Into the 16" C.I. suction header are 4 inch intake dampered laterals, drawing from various points. During 6 years of service the installation has proved a satisfactory remedy. The power cost has been $250 per year, maintenance consisting mostly of replacing the sheet metal fan housing, destroyed by the corrosive moist vapors.

"Controlling the Filter Fly at Flemington, N. J." by WALTER ALLEGAR, Sup't. Treatment Works, Flemington, N. J.

Mr. Allegar's problem, Psychoda fly nuisance from a small trickling filter, was corrected by spraying the filter surface daily with a creosote compound used for destroying lice in his chicken house. The material known as "Carbolatrum" is mixed with Kerosene oil [1 pint in 1 gallon] and hand sprayed in 5 ft. strips across the stone surfaces, particularly where the growths are thickest. From all appearances filter efficiency was not reduced and the treatment once daily during fly season was effective.

"Turbidity Readings as an Index of Sewage Strength and Effluent Quality" by E. ARTHUR BELL, Borough Engineer and Sup't. of Water and Sewerage, Essex Fells, N. J.

Mr. Bell in an earlier meeting had reported on adaptation of the turbidity index of chemically precipitated,

settled, and/or filtered sewage as a satisfactory routine test in operating control. There had been shown to exist a defined relationship between percent purification, as indicated by the suspended solids and B.O.D., and the turbidity readings on influent and effluent samples at three plants. In consequence, the Essex Fells plant is operated on the basis of such turbidity readings as much simpler than daily B.O.D. and Suspended Solids determinations. However, one day each week such determinations are made for the record and correlated.

After two years or more of such operation control, Mr. Bell's data indicates that turbidity reduction on a given sewage is a measure of B.O.D. reduction, when the proper factor is applied for the sewage in question. At his plant the Jackson Candle Turbidimeter is the equipment employed and serves as the most practical test in controlling chemical dosage, which at Essex Fells averages 699.5 lbs./m.g. of alum.

Weston Gavett, Consulting Engr., having also worked with this index of purification, said that he considered turbidity a more exact measure than suspended solids on effluents. The very finely divided colloids did not show up in the solids filtration test, whereas such particles appeared as measurable turbidity.

Alan Darby (Dorr Co.) said that he thought Mr. Bell had contributed something of real value in providing a short cut in laboratory work and a reasonably dependable index. And, H. W. Gehm (N. J. Sewage Exptl. Sta.) added that the method could be applied in treating trade wastes also.

"Maintenance of Sewage Pumping Stations" by A. L. SODEN, Chief Pump Station Operator, Dep't. of Public Works, Trenton, N. J.

Mr. Soden's paper we consider outstanding; so much so that permission is being sought to print it in full in the first available issue. The paper proved about as thorough a discussion on maintenance and operation of sewage pumping stations as we have ever heard. We regret that it was not available for inclusion in the Reference and Data Section of this issue, where it rightly deserves a prominent position as a valuable guide to sewage works managers and operators.

It is very difficult to abstract such a paper effectively because it is about 90% "meat" all the way through, including a complete listing of tools most needed for pumping station work. We therefore suggest that our readers make a mental note to watch for Mr. Soden's worthy contribution in an early issue of this magazine or in the 1940 Proceedings of the Association.

"Pre-treatment of Industrial Wastes, by Industry" by WM. J. KEE, Sup't. of Sewage Treatment Plant of Middlesex Boro, Bound Brook, N. J.

Mr. Kee reviewed progress made by the Borough in the matter of having industrial plants give their wastes adequate pre-treatment for the protection of sewers and treatment plant before discharge to the Middlesex sewers. The ordinance requiring such pre-treatment, and a copy of the legal agreement entered into by Borough and manufacturer, constituted exhibits "A" and "B" with his paper—neither being read because of limits on time.

The Middlesex plant provides chemical precipitation, separate digestion and chlorination.

The ordinance, in brief, requires a special permit to industrial plants to discharge wastes such as are approved by the Superintendent of Treatment and the Borough authorities. It also provides for a special service charge for handling such wastes where any extra expense to the Borough is required.

Waste No. 1 accepted was that from a firm producing glaced fruits, containing salt, sugars, pulp and sulphide with a chlorine demand varying between 100 and 600 ppm. Pretreatment required involves neutralization of acidity with lime and chlorination to satisfy the complete demand. The treatment has been effectively applied since July 1939.

Waste No. 2 is that accepted from a motion picture film producer and developer; clear but rich in sulphides, sulphates, and thiosulphates. Its chlorine demand ran to 5000 ppm. and treatment required consists of lime for pH correction, and incidental precipitation, plus chlorination to full demand. In the beginning 2,000 lbs. of chlorine daily was required, which spurred on successful efforts of the "waster" to install profitable recovery of thiosulphate. Result: chlorine requirement cut in half.

Waste No. 3 for which application has been made, comes from an insecticide producer, contains Paris Green and arsenates. A study made of the effect of such wastes on digestion indicated that a small amount of calcium arsenate stimulated digestion, whereas more noticeably retarded it. All amounts of Paris Green retarded digestion. Since these arsenicals are only sparsely soluble it was decided to require clarification or filtration. The volume being only 7,500 g.p.d. the manufacturer, with a plate and frame filter press, is now filtering and recovering arsenicals at a profit from the operation, and his effluent has caused no disturbance at the treatment plant.

After attempting regulation of discharge from these three treating plants, over a 24 hour period, it did not appear feasible. Now all treated wastes are discharged between 8:00 A.M. and 5.00 P.M., when treatment can be accomplished with one man during daylight hours. Mr. Kee stated that the Borough was thoroughly satisfied with the cooperation on the part of the three industries.

"Correcting Infiltration — the Location and Repair of Sewer Leaks" by JOSEPH R. LECHARD, Chief Engr., Atlantic City Sewerage Co., Atlantic City, N. J.

Mr. LeChard, who has charge of construction, operation and maintenance of the largest privately owned sewerage utility in this Country, always contributes something of value at the New Jersey meetings. This time he discussed the importance of maintaining tight sewers. To preclude infiltration, construction is all carried on with well points so as to obtain a good job and the best possible jointing. Cast-iron pipe is used where ground conditions are especially bad. To hold leakage into Atlantic City sewers to a minimum a yearly manhole inspection is made in the early Spring. Record charts of minimum flows of previous gagings at such key manholes are valuable in detecting and tracing leaks. To locate cracked pipes or leaking joints the fine sand entering from the coastal soil proves an advantage. The source of silt and sand observed in the manhole is traced by pushing rods down sewer and drawing them back into the sand free manhole above the leak. A little sand cup on the head rod returns each time either empty or containing the tell-tale sand. By a repetition of the procedure, each time reaching farther down sewer, the leak can be spotted with considerable exactness. With a ground probe, the spotting is completed from above.

In sewer jointing and repair work a putty made of Portland Cement and pine tar (just enough for a workable putty) is employed. Also cement and water-proofing compound has been successfully employed.

According to Mr. LeChard's ex-

(1) Wm. R. Lafferty, Supt. Sewerage, Lakeland, N. J., and John Boardman, Cons. Engr., Philadelphia; (2) Wm. A. Hansell, Engr. & Supt. Sewerage, Atlanta, Ga., Wm. A., Jr., and Van Porter Enloe, Supt. Clayton Treatment Works, Atlanta, Ga.; (3) Wm. L. Sylvester, Asst. Chief Engr., Dept. of Public Wks., N. Y. City and Leslie West, Chief Engr., Elizabeth Valley Joint Sewerage Comm., Elizabeth, N. J.; (4) J. J. Conway and Jack Van Atta, Ralph B. Carter Co., N. Y. City; (5) P. D. Brandenberger, Supt. Maint. and Constr., and Joseph H. Le Chard, Chief Engr., Atlantic City Sewerage Co.

perience the chief point of infiltration has been loosened joints where house connections enter the Y on the main sewer. To overcome this, collars of concrete are being placed around all such joints.

(In as much as the ground water in areas bordering the sea-coast contains a very high sulphate content, as a rule, as an effective infiltration index, where sand is not so obliging as at Atlantic City, the following may prove worthy. If samples are taken at key manholes during minimum flows and sulphate determinations are made on such samples, with the simple and rapid turbidity method, the findings may tell much. Mr. LeChard points out that water waste into sewers by air-conditioning installations has made flow gagings alone a questionable index in spotting infiltration. In such a case the gaging can be readily checked for "truth" by the sulphate index route. Should anyone try this scheme we will be happy to learn the results and pass them on for the benefit of others.—ED.)

"Sludge and Scum Preheating and Thickening Ahead of Digesters" by THEODORE EGGERSTON, Sup't. of Sewerage, New Brunswick, N. J.

At New Brunswick chemical precipitation effects an 80% to 85% reduction in B.O.D. The sludge filled with fine solids (precipitated) is rather watery. A combination pre-heating and sludge concentration tank is employed in thickening sludge before transfer to heated digesters. The hopper bottomed square tank, containing rows of hot water heating coils on the side walls, is charged from the clarifiers in late afternoon, 250 cu. ft. charges being average. The following morning 100 cu. ft. of supernatant liquor is decanted to the crude sewage and 150 cu. ft. of residual thickened and heated sludge is pumped to the digesters. The preheating has the dual value of better liquor separation and non-chill of the digesters. The process does not create an odor nuisance, because of freshness of solids, iron coagulant and prechlorination of sewage. The temperature of the sludge is raised from 45 degrees entering, to 65 degrees F. leaving. Sludge solids are raised from 1% entering to 4% as the result of overnight thickening.

Operating costs at New Brunswick are $3.77 per m.g.

"Vacuum Drying and Incineration of Crude Sludge" by HAROLD M. PARSELLS, Sup't. of Sewage Treatment, Raritan, N. J.

Mr. Parsells operates one of the smallest treatment plants in America to employ vacuum filtration and sludge incineration. String type drum filters (100 sq. ft. cloth area) discharge a sludge cake containing only 27 to 31% solids to a multi-hearth dryer which reduces the moisture to 30%, taking the shape of sludge "marbles" which are incinerated in the Decarie type garbage-rubbish incinerator. The filter yield is 3 lbs. dry solids/sq. ft./hr., when operating at the most effective speed of 1/5th r.p.m. The crude sludge (4% solids) is concentrated (7 to 9% solids) before ferric-chloride conditioning. Filters operate under 20 inch vacuum and cloths are cleaned by scrubbing with "Oakite" solution after each run and thoroughly rinsed. This care has increased cloth service life very materially.

"Sludge Dewatering and Drying at Tenafly, N. J." by J. K. ADAMS, Sup't., Sewage Treatment, Tenafly, N. J.

The Tenafly plant produces fine screenings and activated sludge, no primary sedimentation being given. The activated sludge has previously been dewatered on sand beds and carted to dump grounds, with results readily imagined. More recently the plant has been equipped with vacuum filters and a Raymond Flash Dryer for filter cake drying. Waste heat from a new and very successful Pittsburgh Des Moines garbage and rubbish incinerator is utilized in the flash sludge drying system.

Mr. Adams said that in operating the new sludge disposal system the chief difficulty had been the very thin Tenafly sludge, averaging only 7,500 ppm. solids and giving low filter yields of 1.5 lbs./sq. ft./hr., thereby requiring unduly long operating hours. In conditioning with ferric chloride the requirement varied up and down between 4.5 and 10%, on the dry solids basis, and was hard to keep abreast of. Filter aids such as "Cellite" had been tried without much improvement. Woolen filter cloths had been found preferable to cotton duck, and washing with "Oakite" cleanser after each run had increased service life of the cloth three fold. At present experiments were under way with a porous rubber blanket known as "Multipore." Air lift for conditioned sludge had proved deleterious to its filterability.

In the Raymond process of sludge drying 5 volumes of the dried product (roughly 10% water) is returned to mix with each volume of wet cake (87% water)—the feed mixture being 50% water. The flash drying unit, rightly named, in 2 seconds reduces the 50% moisture to 10% and discharges a pulverant product. If the moisture drops to less than 10% sludge—fire is a danger.

Concerning operating costs, Mr. Adams reported $42.70 per ton of dry solids, largely because the plant handles only 1200 lbs. of actual solids daily.

Because of the lateness of the hour the Panel Discussion planned on the papers in the Operation and Maintenance Symposium had to be dispensed with. Such was unfortunate because there was ample meat in this group of papers for an interesting discussion by the able discussors chosen.

METERING AND METER SHOP PRACTICE

With Particular Reference to Conditions in Oklahoma City and the Southwest

The Author

By M. B. CUNNINGHAM*
Superintendent and Engineer
Department of Water Supply and Sewerage
OKLAHOMA CITY, OKLA.

Water meters offer an interesting study to the Water Works man, at least I have found this to be so for the past twenty years. Local conditions, such as weather, water treatment, meter housing, corrective meter repairs, and many other factors have a direct bearing on the subject of "Metering and Meter Shop Practice".

In Oklahoma City we have from necessity adopted certain meter shop practices due to local conditions. On the other hand, we have found other cities have some particular type of meter trouble which we do not have here.

In Oklahoma City we obtain our water from the North Canadian River. The water is diverted into a storage reservoir and treated in a lime-soda softening plant. The water is carbonated and we carry a pH of 9.5 in the finished water, based on the Langelier pH—alkalinity stability curve.

Meters In Service

Oklahoma City has 38,000 meters in service, and last year we repaired and rebuilt 3,974 at a total shop cost of $6,770.54, netting an average of about 18 cents per meter in service. Of the total water meters in service, 17,000 are classified as "Old Type Meters," purchased from 1908 to 1920. As a general rule these meters were purchased with the registers without rubber bushings, with open train gears and other items of design and combinations of metals which have contributed to excessive maintenance costs in past years. This leaves 21,000 meters in service which have been purchased since 1920. These, for the most part, are the best type or model now obtainable from the leading meter manufacturers.

The meters in service consist mainly of Cold Water Disc Meters in 5/8", 3/4", 1" and 1½" sizes. However, we do have a few of the Piston Type Meters in these sizes. We also have a large number of 2" Disc Meters, but our standard practice on all meters 2" and over is to use Compound Meters of the Current Type. We also use the multiple system of setting meters, which we find very satisfactory in many instances.

Individual Meter Card Record

An individual meter card record is being maintained on each meter in service in Oklahoma City. This card is made out at the time of purchase and a record is kept of the registration—length of time in service—and the Meter Shop repair cost, which includes both time and material. This record, which is now being completed, will date back to 1920.

Such records are highly useful. They show the advantage in the rebuilding of certain models of meters, where the cost of repairs must be reduced by the use of corrective repair parts, or else the meter junked. The record is also useful for reference when new meters are to be purchased.

Meter Housing

An attempt is made to reduce the cost of meter upkeep by the adoption of an economical yet adequate meter housing. Locked meter box lids have contributed more savings than any single improvement. A concrete meter box is used for the 5/8" and 3/4" size meters. This is a tile, 2 feet deep and has an 18 inch inside diameter at the bottom. A tile somewhat larger is used for 1" meters, and all 1½" and larger meters are set in a precast meter pit, its total depth being 30 inches. The smaller sized meters are set on risers.

We are now making a detailed study of damage suffered in Oklahoma City during the protracted cold wave last January. Weather conditions similar to these occur about once in ten years. From this study we expect to make corrective changes and no doubt we will adopt as a standard setting, a tile having a depth of from 30 to 36 inches. Our average frost line is at 18 inches below surface, with an occasional 2 foot depth during these ten year cold waves. Proper housing and protection for a meter in service certainly contributes markedly to reduce the overall cost of meter upkeep.

Meter Shop Practices

Meter Shop practice in Oklahoma City for the past fifteen years has been to rebuild the water meter coming thru the shop into a meter just as nearly equal to a new one as practice permits. This includes testing the meter, both on the average flow and the minimum flow. This test includes a flow of a quarter of a gallon per minute thru 5/8" meters. Registration of the minimum flow must be from 90% to 100%. On the average or maximum flow, we require the registration to show an accuracy of 98% to 100%. Due to the lime softening of water a slight deposit builds up in our meter chambers, and we believe it is a better practice not to put a repaired meter in service which tests above 100%. The American Water Works practice allows 98% to 102%. (Our Meter Test Bench is here pictured.)

Removal of Meters from Service

Meters taken out of service for repairs or rebuilding at the Meter Shop are ordered out by meter readers. Of all meters ordered out by the readers, 95% have "died" in service. The individual meter card records are beneficial in establishing "safe" registration for the various models and makes of meters. We now have a

*The author, one of the Southwest's most proficient Water Works managers, is serving as Chairman of A.W.W.W.'s up-and-coming Southwest Section.—Ed.

regular program which is followed in the removal of many of these meters. The schedule of removals is based on experience, indicating the need for attention after a meter reaches a predetermined registration, depending upon age, type, etc., of the meters in question. Naturally our schedule may not apply under other conditions, but our experience indicates the high importance of studying conditions and setting up a schedule that proves economically sound in respect to revenue returns vs. costs.

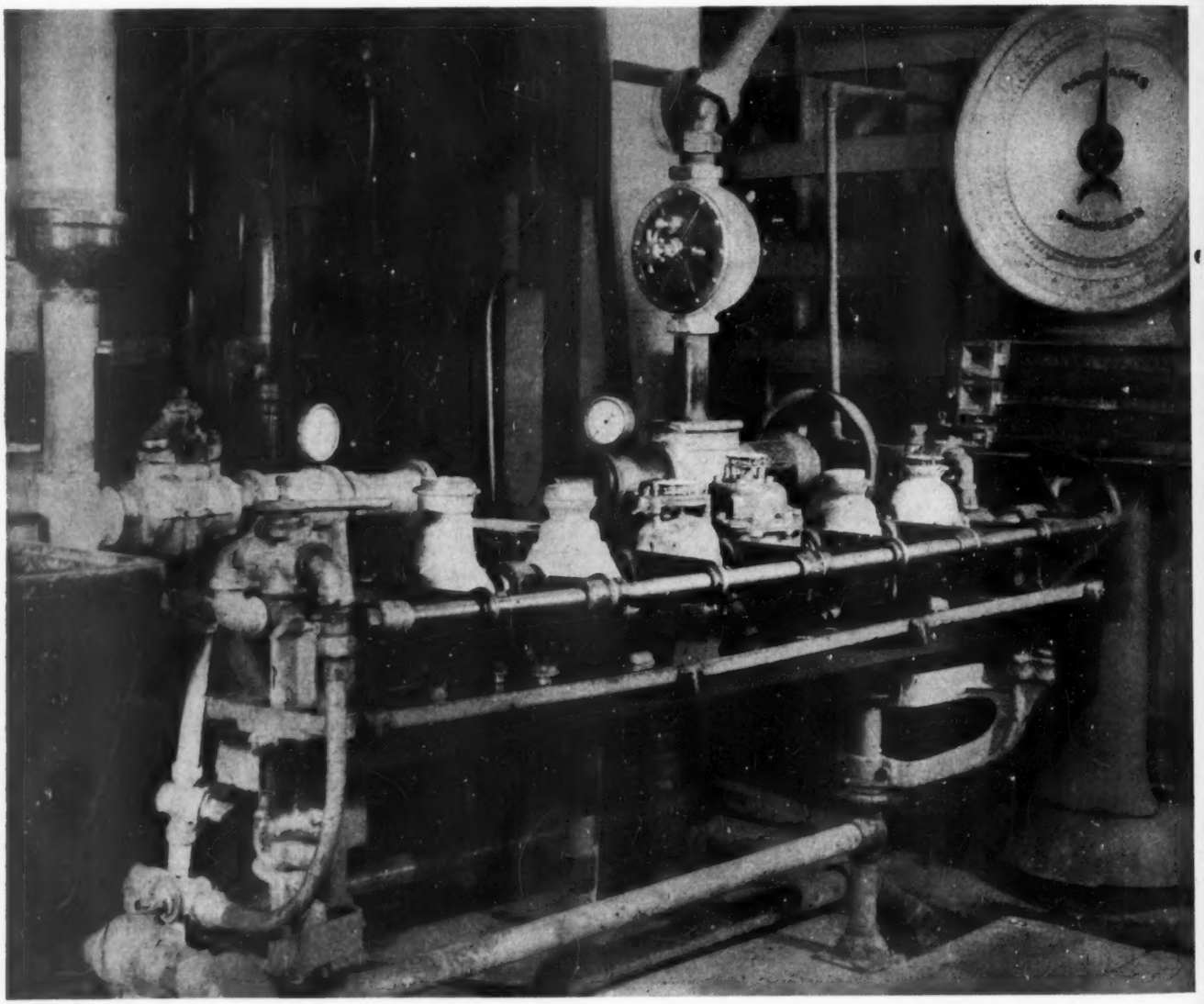
The average water meter in our system goes thru the shop every seven years. It is of importance to note that some meters will only average two or three years in service without shop repairs, while other models need no attention for as much as ten years, dependent of course on the meters compared having been set under similar conditions and having done similar service. We have found that it pays to give serious study to every corrective trouble, even if we have to design the part and determine corrective metals to use in order to properly rebuild the meter. Our experience, and carefully kept cost records, indicate that in changing meters the cost of a man and a car, plus the average cost of making repairs in the shop, will equal half the cost of a new 5/8" meter. Therefore, the less dependable meters which must be repaired twice as often as the more serviceable meters had best be junked, to avoid a running (continuing) net loss. At least this proves sound economy until a really dependable repair procedure can be evolved.

Meter companies have done much in recent years in the way of developing better combinations of metals and higher quality workmanship in meter production. The old meters we find in service, however, continue to present a problem in maintenance and repair.

Shop Methods and Procedure

When a meter arrives at our Meter Shop, the Repairman tags the meter, giving the address and reason the meter was taken out of service. The meter is then placed in temporary storage on the shelves. (See picture.) Our experience has shown us that the proper storage of meters, both before and after repairs, prevents undue damage and extra shop costs.

As a meter starts thru the shop, it is first thoroughly cleaned, inside and out. The brass parts, including the register and intermediate, are cleaned by the use of "Nalco Cleaner" and all parts which have been cleaned with this acid treatment are rinsed in warm water, then immersed in solution of soda and finally washed again



Mueller Meter Tester With Multiple Tester Attached

Air cushion is provided by 4" riser. For quick, positive opening and closure we use a Nordstrom Lubricated Plug Valve. The Fairbanks Scales for the weighing tank has an easy reading chart marked in gallons as well as pounds. At the 10, 20, 50, and 100-gal. points there is a % graduation up to 10% over and 10% under.

in warm water to remove all traces of the cleansing chemicals.

Except for minor repairs, *all registers* and *intermediates* are rebuilt and reconstructed by our Meter Shop Foreman, J. R. Lucas. We have three Meter Repair Mechanics. Each man has his own separate work-bench and the individual mechanic makes the complete repairs, including the preliminary meter testing. The final testing of the meter is done only by the Shop Foreman.

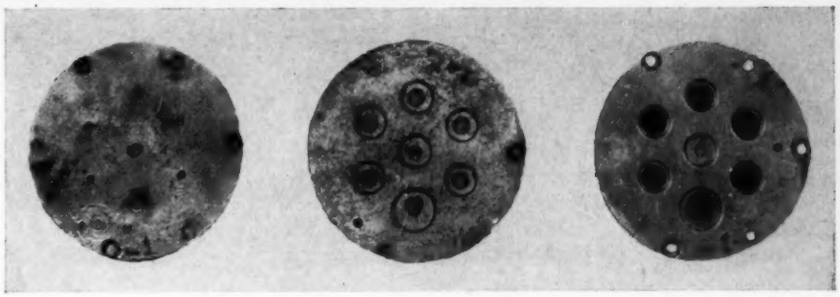
After repairs are made, all meters are closed with rubber stoppers. These remain in place until removed by workmen when the meter is set. This practice keeps dust and dirt out of the meter. A ⅝" spud takes a No. 1 stopper; ¾" a No. 3 and a 1" a No. 5½ rubber stopper, such as any chemical supply or equipment house can supply. Wooden plugs are turned out for stoppering larger size meters.

Meter Registers

On Meter Registers which are rubber-bushed, we use no grease or oil. All registers not having rubber bushings are now either being rubber-bushed, or we are replacing them with new rubber-bushed registers. We have found that excessive use of grease or oil will usually coat the inside of the meter glass and hinders reading of the meter. Our experience has indicated that most animal or vegetable oils will cause brass parts to corrode. Therefore, all grease and oil used in the meters is pure mineral oil, which meets the approval of the meter companies. In one of the pictures appears a register which is undergoing rubber-bushing. In this operation the metal is expanded and punched out by use of a die, which makes it much easier to do the job accurately.

Dials

All new meter dials are carefully examined as to the subdivision of each circle into ten equal parts. If necessary, photographic enlargements (up to 18 inches in diameter) are made of the meter dial, and the dials carefully checked from it. We had one experience where the dials came to us with unequal markings. After the meters were in service for some time, the unequal spacing caused either an over or under-reading of the meter. Of course corrected dials were obtained in this particular case, and the trouble remedied, but not until after a considerable number of complaints from consumers had reached our office concerning questionable bills. This may never happen again, but we now include this examination as one of our routine inspections.



Steps in Rubber Bushing of Meter Registers
(1) *bottom plate;* (2) *metal expanded and holes punched;* (3) *bushings in place.*

Meter dials are also examined on both new and old meters to determine if such have been properly glazed to protect the figures and letters. A few years ago we noticed one particular group of meters had been brought into the shop because the figures and letters had faded off of the dial. Investigation disclosed that these dials had not been properly glazed. We therefore include this as a regular inspection on all new material to avoid a recurrence of such an expense.

All register hands are re-soldered and set back to zero in the Meter Shop. We are careful not to use acid solder.

Register Boxes, which protect the registers, have presented quite an interesting problem. For several years we used a particular rubber gasket under the register boxes to completely seal the lower flange. We would notice the meter register gears badly corroded and often stuck in the bearings. Final analysis of this problem brought out the fact that this particular rubber gasket contained sulphur, or some other compounding ingredient, which resulted in corrosion thru contact with the metal parts. Rubber gaskets used now are purchased free of sulphur or other compounds which might cause corrosion and for the most part we have adopted an available gasket of plastic material. It has eliminated this trouble entirely.

Register Box lids are frequently found broken off of the register boxes. Now a requirement for both new and old meters specifies that the register box lid shall be hinged free, so that it will fall in place by its own weight.

Serial Numebrs are now stamped on both the register box lid and the meter housing. This can be had on

Meter Storage—Oklahoma City Meter Shop
On left; meters awaiting repairs. On right; repaired and lacquered meters ready for service. Note that the latter are closed with rubber stoppers.

all new meters at no extra expense, and it gives us a more permanent record and identification on the meter.

Stuffing Boxes—stuffing box shafts are carefully examined for scoring and are replaced without hesitation, if scored. We have found this saves a great deal of special field service to stuffing boxes by the repairmen.

Overall Length of Meters—Since the meter companies are all turning out a standard overall length of 5/8" x 3/4" meter, we are now adopting a standardization of all 5/8" meters by putting on a 5/8" x 3/4" spud adaptor as rapidly as we are able to make changes in the meter couplings.

Intermediate Gear Trains

All new meters are purchased with the oil-enclosed gears and wherever possible all open gears are replaced with the oil-enclosed trains. The water in Oklahoma City tends to cause excessive friction on the open trains, therefore we believe the oil-enclosed gears, with less friction, give us a more complete registration of water used. Intermediate trains are examined very carefully to determine if the design will give us a reasonable service.

Discs—Until disc material is developed which will not warp under ordinary hot water conditions, it looks like water works men will have to put up with a large percentage of the meters coming to the shop due to damage from hot water. The meter discs, however, will stand temperatures 50 degrees higher than those furnished the water works trade a few years ago.

Measuring Chamber — We have had some excessive corrosion develop in some of our division plates or diaphragms on some of the smaller sizes of disc meters. We therefore check very carefully all disc chambers to determine if the division plates are of similar metals to the measuring chambers. While we have had this trouble, I have heard considerable complaint that some cities are having trouble with slots wearing out. However this trouble we do not have in Oklahoma City.

Workmanship in the Meter Shop —We encourage our meter mechanics to take pride in their work and that the word "workmanship" is to be construed in its full meaning and intent, and shall be strictly first class in all respects, not merely ordinary or according to common practice.

Materials Used in Meters

In Oklahoma we have to be very careful to obtain similar materials in water meters to avoid galvanic action and electrolytic corrosion. Whether it is a new meter, or an old one, we give especial attention to the problem of obtaining a meter having a high grade metals and of similar characteristics throughout. This requirement is based upon our experience with water meters in Oklahoma City where corrosion occurs when two dissimilar metals in contact with each other are immersed in water. Electrolytic action is checked by the use of a galvanometer. Analysis of metals is made by L. H. Scott, Filtration Engineer, who employs a spectroscope for the purpose.

Meter Painting

All meters repaired are sprayed with a coat of Duco Lacquer, metallic in color. The small cost involved, we believe, is justified since it tends to protect the meter housing, and the meter is easier cleaned. It gives the meter a neat appearance, which is of high importance, in indicating to the average consumer that his meter has been given high grade treatment in the shop. One of the pictures shows the spray painting cabinet, which houses the meter on a turn-table. An electric blower exhaust carries away the fumes of the lacquer. An expert workman can spray two 5/8" meters per minute. One quart of Duco (metallic), mixed with one gallon of thinner, will cover 100 meters of the 5/8" size. Cost averages two cents per 5/8" meter.

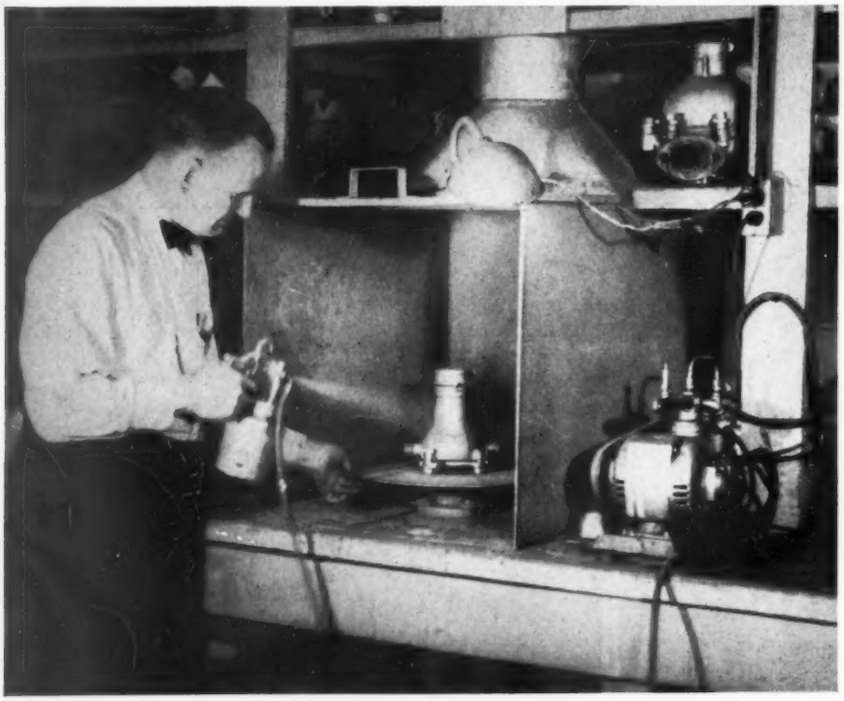
Special Tools

A special meter vise is used by the Department, which holds 5/8" and 3/4" meters in any desired position. This allows the workman to use both hands with his tools. Before this meter vise was developed, our workmen frequently were injuring their hands and fingers due to a lack of tools to hold the meters properly. Lost time caused by injury is expensive and we can assure the reader that a meter vise is well worth the investment.

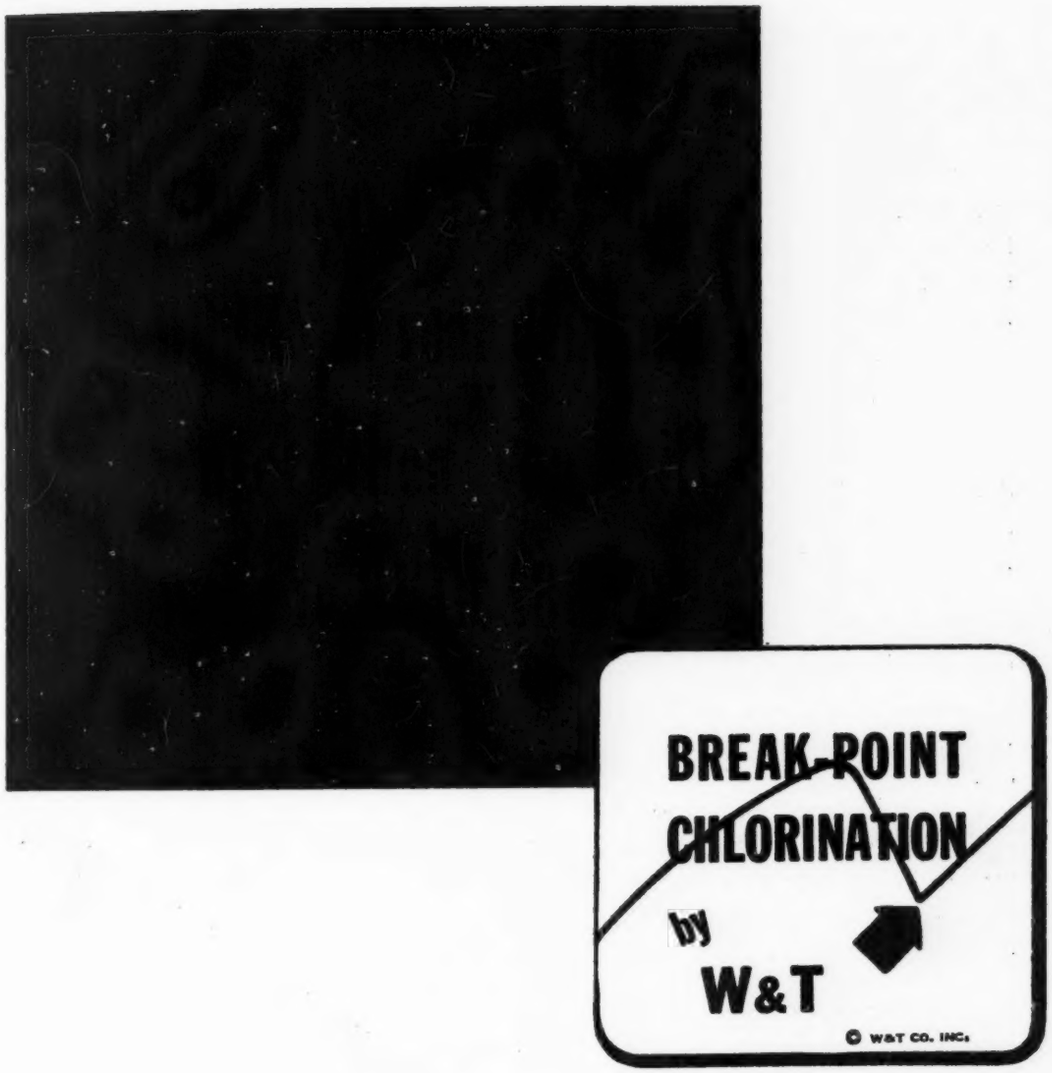
Air nozzles are provided for cleaning out bearing and for other uses around the work bench. Electric emery wheels are provided. A rubber wheel replaces the emery wheel for various uses around the shop. Buffing wheels which run at high speed are also provided, with both wire and cloth polishing wheels for cleaning off corrosion and polishing parts where necessary.

An Ounce of Prevention — The Oklahoma City Fire Department saves thousands of dollars each year by preventing water damage at fires. We have likewise found that a lot of meter repairing can be saved by preventing undue damage to meters. Such damage *prevention* consists of *proper installing; housing; protection from damage in service; careful handling* while being removed to the shop; and care while in the shop.

In conclusion I should like to emphasize, above all else, the advantage of truly *correct* rebuilding of meters to fit local use and conditions.



Introducing Our Meter Shop Foreman—J. R. Lucas
He is demonstrating for you how we metal-lacquer a 5/8" meter for the cost of 2 cents.


BREAK-POINT
CHLORINATION
by
W&T
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An Important Statement from Wallace & Tiernan on the Subject of Water Chlorination

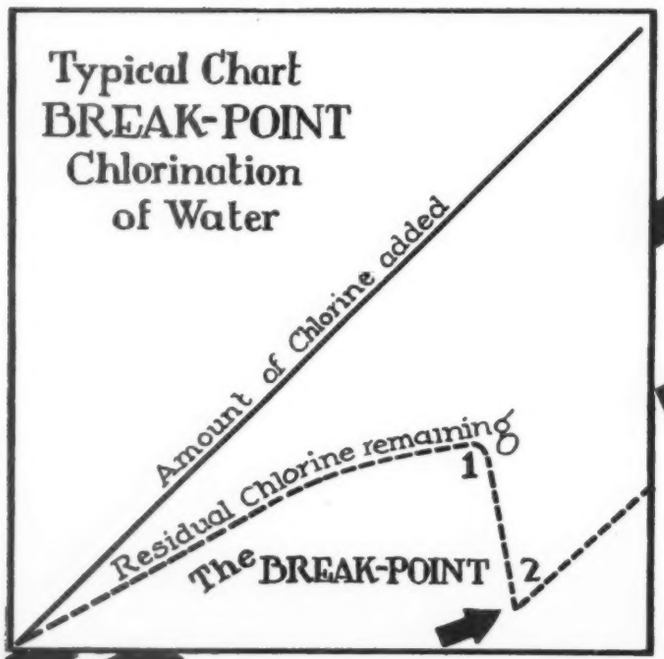
ABOUT forty trillion gallons of potable water have been chlorinated through the use of W&T equipment since we pioneered in the manufacture of Chlorinators in 1913.

From the early days of simple final chlorination, there have followed in rapid succession pre-chlorination and post-chlorination, chlorination with or without combinations of various iron salts as an aid to coagulation, successive or stage chlorination at various points in the system, chlorination for filter bed sterilization—for crenothrix control—for algae prevention—for main sterilization—and with ammonia (to form mono-chloramine and di-chloramine) to create long-lived residuals throughout all the distribution lines.

During the past two years there has been what we consider to be a most important development in the field of chlorination of drinking water—a development that in many cases promises to go far toward solving a major water works problem—THE REMOVAL OF TASTES AND ODORS IN WATER, as delivered to the consumer.

This development has come about because of a better understanding of what happens when chlorine is added to water. It is the result of the work of a large number of independent investigators, many of whom have worked in collaboration with our research chemists. It is the result of tests and operations on a large number of water supplies under varied conditions.

Many waters suffer seasonally or even continuously from taste troubles [illegible] may be due to organic matter such as the oil from algae or protozoa. Th[illegible]ay be the result of phenol or trade waste pollution—or, simply the high [illegible]nic content of tributary streams. Such tastes are often intensified by chlori[illegible] at the heretofore normal rates of [illegible]cation.



The qu[illegible] is how to eliminate these tastes? T[illegible]nswer is: Destroy them. How? By [illegible]ing a sufficient amount of chlo[illegible]ne water so that there will [illegible]n no organic matter with which [illegible]e chlorine can combine to produce ta[illegible]

And out of these conclusions has come . . . . . .

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BREAK-POINT CHLORINATION by W&T

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CHLORINATION TO THE BREAK-POINT is a convenient way of describing the phenomenon produced in many waters when very much larger rates of chlorine are applied than has heretofore been customary standard practice. Hundreds of tests have shown that with most waters there is a rate of chlorine application that will be sufficient to break down taste producing organic matter and at the same time leave residual chlorine at a minimum.

If insufficient chlorine is applied, the taste producing organic substances remain in the water. If too much chlorine is added, then chlorinous tastes are liable to be formed. The problem is to find the BREAK-POINT. This is not a simple matter. It is not a case of just opening up the control valve on a chlorinator and "letting her go"—such a procedure may increase rather than decrease tastes and odors. Each water presents a specific problem and the BREAK-POINT can be determined only by special tests made on the job.

The chart opposite illustrates what happens in a typical water, chlorinated to the BREAK-POINT. With chlorination as previously practiced, using applications of from one-tenth to one part per million, as the rate of chlorine application increased, the residual chlorine remaining in the water increased as shown on the chart,—this increase being in decreasing proportion to the application. As more chlorine is added, the curve indicating residual chlorine flattens out: and higher rates of chlorine application show little or no increase in residual chlorine. See point (1) on the chart.

As further chlorine is added, the application becomes adequate to break down the taste producing organic substances, and most of the chlorine is used to oxidize organic compounds. At point (2) residual chlorine is at a minimum—and tastes and odors disappear. This is the BREAK-POINT. Chlorination beyond point (2) increases the residual progressively with successive additions of chlorine.

The results which have been secured by BREAK-POINT Chlorination in a large number of instances have been so spectacular as to be almost unbelievable. Tastes and odors so severe as to bring an avalanche of complaints from consumers have been eliminated. Sources which otherwise would have been abandoned have been continued in use—and all by the simple expedient of chlorinating to the BREAK-POINT.

The determination of the BREAK-POINT is a scientific study, requiring spe

laboratory technique and experience. Some waters do not have an easily recognized BREAK-POINT, but in a surprising number of cases proper tests and studies indicate a rate of chlorine application at which the same results are produced. Then too, occasionally—but rarely—a particular type of organic pollution will create tastes that, though greatly reduced, will continue through the BREAK-POINT. Sometimes subsequent dechlorination is indicated; but, if the true BREAK-POINT is reached, usually dechlorination is not required.

All of which emphasizes the point we wish to make, namely: that BREAK-POINT Chlorination is not a cure-all for all tastes and odors, but that in the great majority of supplies, after proper study and under proper scientific control, BREAK-POINT Chlorination is the answer to taste and odor difficulties and we recommend its careful consideration for use on all water supplies having taste and odor problems.

The water supply profession and industry are indebted to the many independent investigators who have pioneered this new interpretation of a previously observed but little understood phenomenon—and W&T is grateful to them for the unselfish way in which they have made their data available to our field chemists.

All W&T men are equipped to discuss BREAK-POINT Chlorination with your consulting chemist or engineer—or with your plant chemist or superintendent. We will recommend BREAK-POINT Chlorination only after special tests made on the job; but there is a W&T man near you who will be glad to call if you will communicate with our nearest office.

Meanwhile, you will want to have a copy of W&T's Technical Publication No. 207 "Taste and Odor Control with BREAK-POINT Chlorination." The coupon will bring it to you.

Incidentally, BREAK-POINT Chlorination will be featured at W&T's exhibit at the Annual Convention of the American Water Works Association at Kansas City, April 21st to 25th. One of our Field Research Laboratories will be on exhibition and BREAK-POINT determinations made at our exhibit during the Convention.

"The Only Safe Water is a Sterilized Water"

Wallace & Tiernan Company, Inc.

Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK NEW JERSEY

BRANCHES IN PRINCIPAL CITIES

WALLACE & TIERNAN CO., INC. Newark, New Jersey—W.W.S.

I want to know more about "Taste and Odor Control—With BREAK-POINT CHLORINATION." Please send Technical Publication No. 207—FREE.

NAME.....

STREET.....

CITY.....

STATE.....

POSITION.....

HOW'S YOUR "C" LINE?

It's a Wise Operator Who Watches It; and It's Not Overly Difficult to Do So

"Doc" Taylor

By D. R. TAYLOR
Plant Superintendent
Water Department
ROANOKE, VIRGINIA

YOU probably know men who report to their physicians regularly for physical examinations. These men are not concerned about the surface of their anatomy—they can see that; they want to know the trend of that part of their "human plant" that is under the surface.

Among other things, they want to know the friction loss in their circulatory system, and if an increase of this friction is causing a diminution of capacity and a corresponding dissipation of power. They are anxious to take immediate and proper remedial action if the friction is building up too fast and capacity is falling.

How Are Your Water Arteries?

Realizing that probably 80% of the worth of your water works "anatomy" is represented by its "arteries," also hidden under the surface, leads to the question—How *old* are your water supply arteries? And I do not mean in years, but in the matter of "oldness" in terms of that all important criterion—friction build up and failing capacity. Only if you are watching your "C" line will you know; otherwise you can only be guessing.

How to Find Out

The "C" Line I refer to is no other than the important line to show the status and trend of the coefficient of friction of pipe lines which you have frequently heard referred to as the "C" value of mains.

Determination of the "C" value derived from the famous Williams & Hazen formula may sound formidible and difficult but it really is not and I hope to be able to convince you of as much by showing how relatively simple it is to secure the needed test readings on a length of main and derive therefrom the "C" value (friction coefficient). In short, how you can answer the question—How old are your "arteries"?

This type of work is not only interesting but is full of surprises. It is the most positive and effective method of determining the necessity for reducing the friction in these important arteries and the need for treatment to prevent corrosion. Then, afterwards, what the results of such treatment are. Likewise, if there are advantages to be gained in the use of lined pipe. Finally, as an added guide in planning future developments and additions. After you have selected and tested sections of representative mains, you will have enough curiosity to make a second test within six months, after which an annual check-up is usually sufficient, depending upon results obtained.

The computations necessary are not as intricate as the average water works operator seems to think they are. You need not worry about being "rusty" in the use of a slide rule and unfamiliar with logarithms. You do not need to have a dizzy spell when you see the formidable looking formulae.

A Simple Method of Finding "C" Values

Herewith is a tabulation of diameters and areas of both pit cast and super deLavaud Cast Iron pipe which is self-explanatory, and, although "slipped off" on a slide rule, is sufficiently accurate for the work. I am also enclosing a data sheet presenting two logarithmic curves, the necessary formulae, conversion factors and explanation of symbols. These are all that I find necessary for ordinary purposes in solving flow problems.

In the upper right hand corner of the graph sheet are the simple formulae for determining quantity, velocity, and areas. Formula (1) in the center of the sheet is the original Williams and Hazen formula for the solution of velocity. It is more simply expressed in formula (2). Formula (3) is that employed in calculating these "C" values. Formula (4) is for the solution of "S," which represents hydraulic slope or friction loss. Formula (5) gives the same value more simply.

Procedure

Suppose that you are testing a section of unlined pit cast main with a nominal diameter of 10 inches. Say it is 800 feet long between pressure gauges, and that the measured rate of flow from the hydrant at the far end was 1036.8 gallons per minute. Let us say that the pressure drop between stations (shown by the difference in readings of the two pressure gauges) was 7.13 lbs./sq. in. This represents the friction loss (S) for the 800 ft. run between these two points.

Now, what is the coefficient of friction ("C" value) of this main?

By reference to the formulae on the data sheet we will find that

$$Q = 1036.8 \text{ g.p.m.}$$

$$Q = \frac{1036.8}{448.83} = 2.31 \text{ c.f.s.}$$

$$V = \frac{Q}{A} \text{ and } A = .5454$$

(10″ pipe table 1.)

$$V = \frac{2.31}{.5454} = 4.225 \text{ ft./sec.}$$

The hydraulic radius of 10″ pipe
R = .2083 (from table).

Friction loss (hydraulic slope)
S = 7.13 lbs./sq. in. (for 800 feet)

Convert to feet loss
$= 7.13 \times 2.31 = 16.47$ feet
Per foot of main:

$$S = \frac{16.47}{800} = .0206$$

Now for the formula

$$C = \frac{V}{1.318\ R^{0.63}\ S^{0.54}}$$ in which

$R^{0.63} = .2083^{0.63}$

Although shown in the table, this value can be secured from the graph as follows: On the base line, we locate .2083 (R). From this point, move vertically up the sheet to intersect diagonal "B"; thence horizontally to the vertical axis, where we find 0.372. Therefore $.2083^{0.63}$ is 0.372.

In a similar manner, by intersecting diagonal "A," by following up the .0206 (S) line from the base, we find:

$S^{0.54} = (.0206^{0.54}) = .1225$

Therefore; according to the formula

$$C = \frac{4.225}{1.318 \times .372 \times .1225} = 70.3$$

In use of formula (5), by employing curve "A" "in reverse," any number raised to the 1.85185th power can be had.

For instance, using the above values in formula (5)

$$S = \left(\frac{4.225}{1.318 \times 70.3 \times .372}\right)^{1.85185} = .1225^{1.85185}$$

Find .1225 on the vertical axis, move horizontally to the right to diagonal "A" and then drop down to the base line, and we find .0206.

Therefore; S = .0206.

In order to be as brief as possible this explanation may require a little close study. However, the information should prove sufficient for fairly accurate evaluations.

Let me warn you though to caliper the hydrant nozzel through which the rate of flow is determined. Contrary to the common assumption, this diameter is rarely exactly 2½ inches.

If, after you have pursued this task for a while, your enthusiasm becomes more acute and the magnitude of your study warrants it, you might purchase two calibrated precision altitude gauges to replace your pressure gauges and a K. & E. log-log duplex decitrig slide rule, which is not nearly as difficult to use as you might think. With the use of the log-log scales on this rule, you can accurately and quickly determine the fractional powers or roots of numbers, and the decimal points are shown in each case. Furthermore, if all of this eventually leads to a complete comprehensive study of your entire distribution system, the purchase of an hydraulic slide rule (based on the Williams and Hazen formula) will be a good investment. With any great volume of hydraulic computations to be done, the answers can be rapidly determined with one of these rules, which are just as easy to use as the ordinary slide-rule.

CAST IRON PIPE DIMENSIONS
and Hydraulic Radius Values

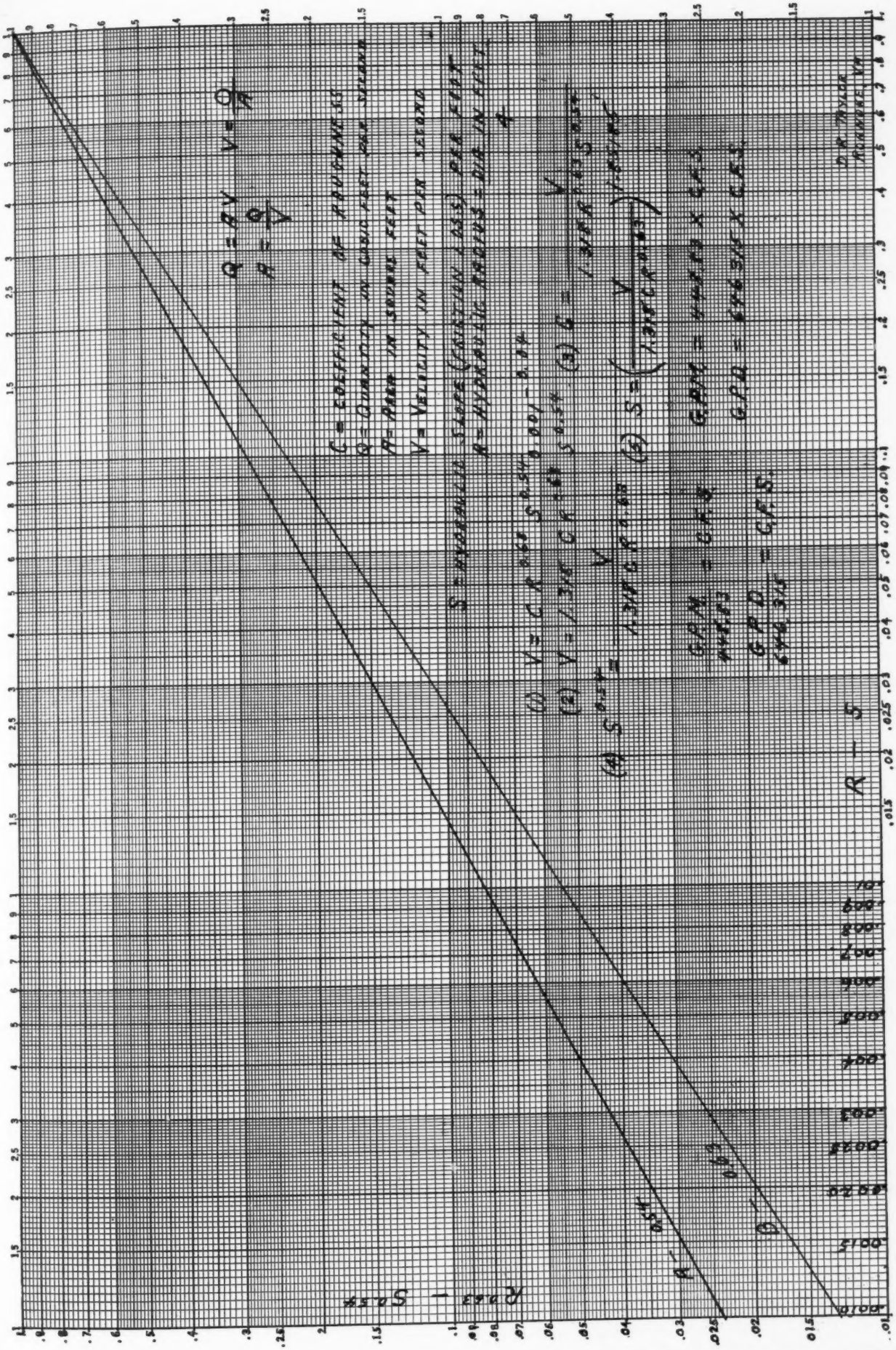
TABLE 1.

	Nominal Standard Dimensions				Actual Standard Dimensions							
	All Cast Iron Pipe				Pit-Cast Class B				Super Delavaud Class 150			
					Unlined		Cement Lined		Unlined		Cement Lined	
Nominal Diameter	Area Sq. Ft.	Diam. Feet	$R = \left(\frac{\text{Diam. Ft.}}{4}\right)$	$R^{0.63}$	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet	Area Sq. Ft.	Diam. Feet
2"	.0218	.1667	.0417	.135	.0218	.1667	.0192	.1562				
3"	.0491	.2500	.0625	.175	.0532	.2600	.0490	.2495	.0539	.262	.0495	.251
4"	.0873	.3333	.0832	.209	.0915	.3418	.0825	.3240	.0920	.342	.082	.322
6"	.1963	.5000	.1250	.270	.2060	.5120	.1890	.4900	.207	.513	.190	.492
8"	.3491	.6667	.1665	.324	.3520	.6690	.3300	.6490	.367	.685	.346	.663
10"	.5454	.8333	.2083	.372	.5420	.8300	.5150	.8100	.562	.8465	.536	.826
12"	.7854	1.0000	.2500	.417	.7820	.9960	.7500	.9760	.812	1.016	.780	.996
14"	1.069	1.1667	.2917	.460	1.065	1.1640	1.005	1.132	1.152	1.212	1.100	1.180
16"	1.396	1.3333	.3330	.500	1.398	1.3320	1.332	1.302	1.500	1.382	1.440	1.352
18"	1.768	1.5000	.3750	.539	1.768	1.5000	1.700	1.470	1.890	1.550	1.820	1.520
20"	2.182	1.6667	.4167	.576	2.182	1.6670	2.100	1.635	2.340	1.725	2.250	1.692
24"	3.142	2.0000	.5000	.647	3.142	2.000	3.060	1.972	3.350	2.062	3.25	2.035
30"	4.909	2.5000	.6250	.744	4.880	2.4950	4.720	2.451				
36"	7.069	3.0000	.7500	.834	7.080	3.0000	6.840	2.958				

Dear "Bill"—

This was originally written in the style of my earlier open letters to readers of W. W. & S. However, ye Ed.! blue penciled my "Dear Bill" stuff and made it into a paper. I hope you do not get the idea that I'm getting "high-hat," and please feel free to write me if there may be some ambiguous spots in this discussion, which I tried to make as brief as possible. You may have to study it a little closer on that account, but write me if I can help clear up any point.

Yours, etc.—"Tom."


Q = AV
V = Q/A
S = Coefficient of roughness
Q = Quantity in cubic feet per second
R = Area in square feet
V = Velocity in cubic feet per second
P = Hydraulic radius in feet
R = A/P
(1) V = 1.318 C R^0.63 S^0.54
(2) V = 1.318 C R^0.63 S^0.54
(3) S = 0.0004 V^1.852 / R^1.167
(4) S = (V/1.318 C R^0.63)^1.852
Cast Iron C = 130
Riveted Steel C = 110
Concrete C = 100
Wood Stave C = 120
Vitrified Pipe C = 110
Cement Lined C = 140
Asphalt Dipped C = 140
Tuberculated C = 100
Dr. Taylor
Hydraulic Val
R^0.63 S^0.54
S
R
A
B

CORROSION CONTROL AT LEWISTON, IDAHO

By W. P. HUGHES, City Engineer*
Water Superintendent
LEWISTON, IDAHO

LEWISTON, IDAHO, can trace its history back to the expedition of Lewis and Clark in 1805. The explorers camped on the site where the city now stands on their westward journey, and in honor of Meriwether Lewis the city was named Lewiston.

Lewiston, being one of the first cities in the Northwest to practice corrosion control by maintaining calcium carbonate saturation of the finished water, a few facts concerning the conditions met and methods used may be helpful to others, especially in the section mentioned.

"Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive water should be treated." (John R. Baylis in "Treating Water to Prevent Corrosion.")

Source of Supply

The Clearwater River, source of Lewiston's water supply, heads high up in the Bitterroot mountains near the Montana line, and is fed by countless beautiful lakes and streams, surrounded by rugged, heavily timbered mountainous country. The Clearwater drains an area of nine thousand four hundred square miles, with about seventy-five per cent in National forests. In flow, it ranges from 2,000 to 140,000 second feet, a quantity of water sufficient for a city many times as large as Lewiston. This water is typical of most corrosive waters. It is very soft, with a bicarbonate alkalinity average of about 22 p.p.m and pH of 6.9 or 7.0.

*The author, a past Director of AWWA, is now President of the Pacific Northwest Section of AWWA and the Northwest Sewage Works Association.—Ed.

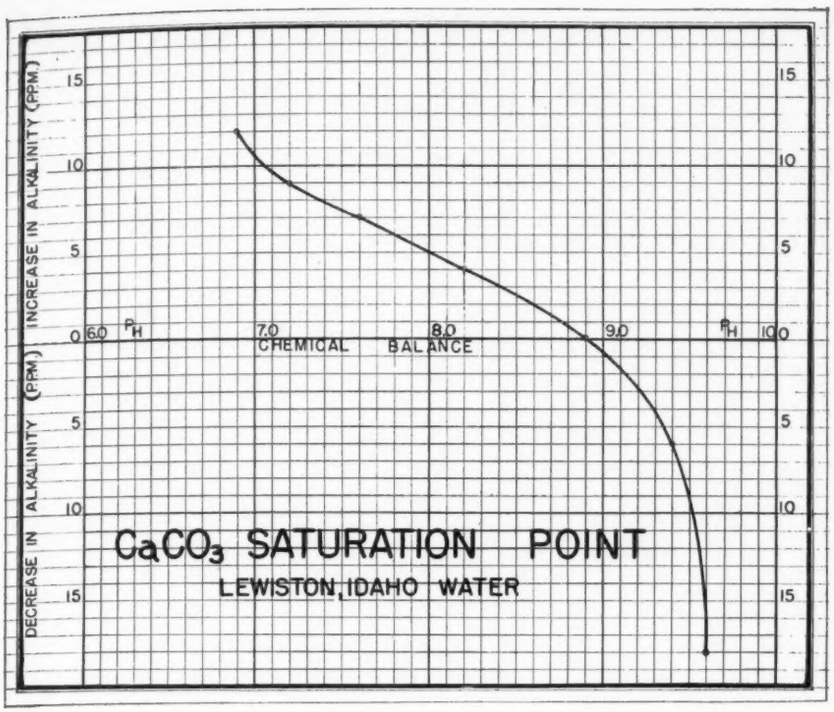
The Author

The following is a chemical analysis of the raw water:

Constituents	*Parts per Million*
Silica (SiO_2)	10.
Iron (Fe)	0.08
Calcium (Ca)	9.4
Magnesium (Mg)	1.3
Sodium (Na)	2.6
Potassium (K)	0.9
Bicarbonate (HCO_3)	26.
Sulphate (SO)	14.
Chloride (CI)	1.4
Nitrate (NO_3)	0.14
Total dissolved solids	57.
Total hardness as $CaCO_3$ (calculated)	29.

When the supply was pumped directly from the Clearwater River, without filtration, it was not corrosive to the same extent as it has been since filtration. This fact puzzled many old residents and led them to ask what chemical was put in the water that caused hot water tanks to rust out so quickly. This condition is easily explained. Before filtration, the water contained organic matter, emulsoids, and very fine clay in suspension. These substances adhered to the inside of the pipes and hot water systems, forming an efficient protective coating. After filtration, these substances are no longer present. The pH of the fin-

Lewiston's Filtration Plant and Pumping Station.



Calcium Carbonate Saturation Index Curve.

As it developed for Lewiston's filtered water. (When the hardness rises this curve drops back to give a balance point as low as pH 8.5, but ordinarily the point is at pH 8.8.)

ished water would have been lowered too, but enough lime was added to hold the pH at 7.4.

Lewiston's Method of Correction

Following filtration, corrosive waters must have something added to form a protective coating in the distribution system. Lime is in more general use for this purpose than any other chemical. It is usually cheapest and most effective. Hydrated lime is used in this instance.

By means of dry feed machines aluminum sulphate and lime are used for coagulation at an average optimum pH of 6.8. The first application of lime is to the mixing chamber to obtain proper pH for alum flocculation. The second dosage of lime is for the purpose of bringing the pH of the water up to the saturation point for $CaCO_3$. A number of points of application were tried to determine the most effective point for second dosage of lime. After consideral experimentation, it was found that application to the filter influent gave best results, with fewer undesirable features. Applying all of the lime treatment at any point in the mixing chamber, or just beyond, interfered with proper floc formation, due to the narrow pH range for efficient coagulation. Adding lime in the clear well after filtration caused very objectionable deposits of insolubles and permitted fine particles of undissolved lime to be swept into the pipe system. Placing the dosage in the filter influent will cause the filter sand to grow in time, the rate of growth being in proportion to the amount of lime used. In our case such has been of no consequence. This method has the advantage of removing the finely suspended undissolved lime particles by filtration and it doesn't interfere with the floc or cause it to redissolve. The tests for free aluminum compounds in the finished water furnish conclusive evidence that the lime does not redissolve our floc. Small pieces of lime incrustation from the feed machine came in on the filters at first, but by moving the point of application from inside the filter influent weir to just ahead of it, this has been entirely overcome.

Laboratory Control

When treatment was first begun the proper total alkalinity and pH, indicative of the stability point as determined by the use of Baylis's $CaCO_3$ curve and the marble test, were determined. The second application of lime was then gradually increased until the revealed optimum pH (8.8) was reached. Later a series of cut and try tests were made similar to those outlined by P. L. McLaughlin,* except that six half gallon jars and the laboratory stirring machine were used. A quantity of finished water which had received no second lime treatment was brought to the laboratory. This was placed in the jars and a series of increasing lime dosages were applied that would with certainty extend beyond the saturation point. The stirrer was turned on and after thorough mixing and the jars allowed to settle, the pH and alkalinity of each jar was taken and

* "Water Works and Sewerage," March, 1936 and 1937 and 1938 Reference and Data Sections of this magazine; also "Water Works Engineering," March, 1936.

Interior of Lewiston's Filtration Plant.

recorded. Then an excess of pure precipitated $CaCO_3$ was then added to each jar and stirred for thirty minutes—a modification of the marble test.

The $CaCO_3$ was permitted to settle after which a sample from each jar was carefully filtered, and the pH and alkalinity again determined. The increase or decrease in alkalinity of each was then plotted on a curve against the pH of each sample before the carbonate was added. This curve shows the "$CaCO_3$ Demand" in p.p.m of alkalinity up to the saturation point, and also the degree of supersaturation beyond that point. (See cut.)

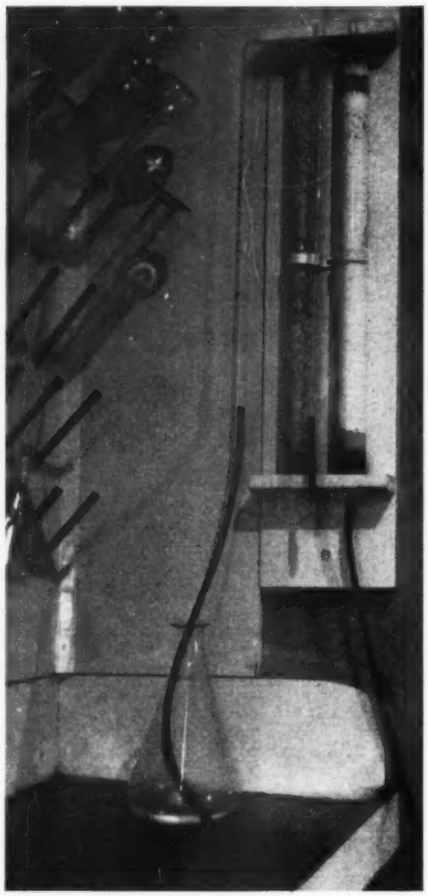
For corrosion treatment to succeed, the finished water must be maintained in chemical balance—i.e., at the saturation point for $CaCO_3$. Sometimes it is desirable to go a little beyond the saturation point for a time to form a thin coating of $CaCO_3$ in the mains or to add to that already formed. It is important that the balance be carefully controlled. Careless or indifferent methods of treatment and control are simply a waste of that much money in time and chemicals.

Continuous Stability Indicator Proves Great Asset

Enslow's Continuous Stability Indicator has proved to be a wonderful help and convenience in the laboratory and at the same time an inexpensive piece of equipment, easily installed. By means of this simple apparatus, conceived by Linn H. Enslow, it can be learned whether the finished water is being carried at the saturation point with a minimum of effort and in a few minutes' time. Langlier's Corrosion Index, or something closely approximating such, can be obtained by means of it, without detailed analysis or complicated calculations.

Fundamentally, this device consists of two tubes of glass or other material supported in a vertical position. One is filled with powdered or finely ground $CaCO_3$, and the other with marble chips. (See cut.) These have plugs of glass wool and one hole rubber stoppers at either end. The tubes are connected in series and a very small stream of the water to be tested is allowed to flow through continuously. The rate is controlled by stop cocks or some other device.

The pH of the water is taken before and after passing through the Stability Indicator. If it is the same in both instances, the water is in chemical balance to $CaCO_3$. Should the pH increase on passing through, the water is under-saturated and will remove the $CaCO_3$ coating from the pipe lines. If it decreases, the water is super-saturated and will deposit $CaCO_3$. The rate of flow through the indicator must be controlled by the contact period necessary to obtain saturation. A Saturation Index is obtained by subtracting the difference in pH values. Enslow's article in May 1939 issue "Water Works and Sewerage," Data Section page 229 describes and illustrates the Stability Indicator. [A revision of this article, based on experience, will be found in the Data Section of this same issue—Ed.]



Our Enslow Continuous Stability Indicator

(Has proved to be an almost indispensible piece of equipment in simplifying control and maintenance of a carbonate balanced water. It truly "works while you sleep" and there can be no questioning its revelations to the operator.)

The Effects of Corrosion

A small amount of tuberculation will have a very decided effect on the friction head of transmission lines and cause an unseen power loss that would pay for a great deal of corrosion control treatment. The fact that no red water complaints are received, does not mean there is no corrosion. Extensive tuberculation can take place in a pipe line without causing any red water complaint whatever. The only way of being sure a water is not corrosive, is by careful laboratory test, treatment control, and examinations of sections of pipe in the field. Corrosion is especially apparent in fittings. Many corrosive waters are not recognized as such by operators and it is well to consider the fact that power losses may possibly be materially reduced by applying corrective treatment considered now as unnecessary. Why not give the department and consumers the benefit of a stabilized water with a good margin of profit in most instances? Another heavy loss might be the necessity of main replacements before the expiration of the normal life of a pipe line.

The effect of even slight corrosion on pipe carrying capacity is hard to believe by the average operator who has not gone into the matter and given it study. The following data compiled by the "Committee on Pipe Coefficients" of the New England Water Works Association shows this loss of carrying capacity. These figures are from tests made in the field on pipe lines in actual service carrying water of different pH values for the period indicated. It points to the value of corrosion controls as nothing else could so thoroughly do. This table is based on data collected all over the country and plotted in respect to pH of waters involved and data on the coefficient of friction observed for each main tested.

Reduction in Capacity of Cast-Iron Mains Due to Corrosion and Tuberculation

pH Value	*% Capacity Loss**
6.0	85
6.5	60
7.0	45
7.5	35
8.0	30

*Loss in carrying capacity during a service period of 30 years.

A great deal of the success of our corrosion control work is due to the efficiency and fine cooperation given me by our Filter Superintendent, Winston H. Berkeley, who, previous to coming to Lewiston, was for six years Assistant Operator of Purification at the Wenatchee, Wash. water plant. Incidentally Mr. Berkeley is one of the first operators to be promoted in this section to another plant, in accordance with the policy as laid down by the Short Schools for Waterworks and Sewage Operators, which is one of the functions of the Northwest Section of A.W.W.A.

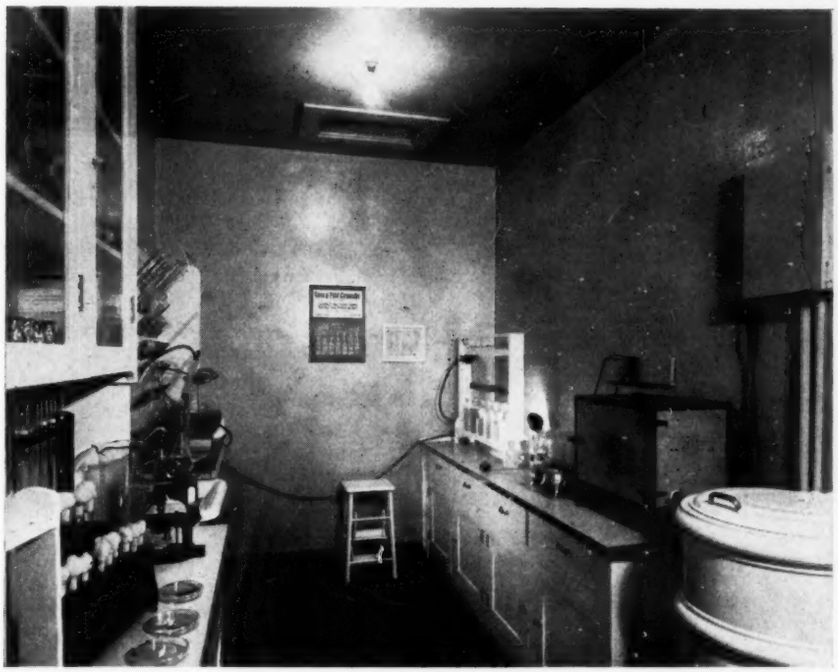
Summary

Lewiston having always fed some lime and maintained a pH of about 7.4, the corrosion has not been severe, being mostly confined to fittings. Evidence indicates that the present program of maintaining a carbonate saturated water is giving results well worth the cost of the treatment. Sections of test pipe in the plant show a soft gray coating and very little or no corrosion.

The water leaving the plant has a normal carbonate alkalinity of 4 to 6 p.p.m. (pH of 8.5 to 8.9) and a carbonate alkalinity of 28 to 30 p.p.m. The soap hardness is between 40 and 50 p.p.m. The dissolved oxygen is about 8 c.c. per liter. There is of course, no free CO_2.

Samples of water from dead ends and far removed from the plant show upon examination in the laboratory that the water is very nearly uniform in quality throughout the system, any differences being too slight to be worthy of note.

The seasonal changes in the water make it difficult to give figures but it requires about 0.69 gr. per gal. of hydrated lime to raise the pH from 6.9 (the pH of coagulation) to 8.5 to 8.9. The saturation point in respect to $CaCO_3$ is the basis of control, and is found within the range pH 8.5 to 8.9, which reflects the changes in total alkalinity and hardness content of the supply, the required pH dropping with increasing calcium hardness.



Our End of the Laboratory of the Lewiston Plant.

Note the stirring machine for making jar tests in flocculation control and formerly in determining the correct line application to reach the calcium carbonate saturation point.—see curve. This picture was taken before Enslow's Continuous Stability Indicator was installed on the wall above the sink.

"TAKEN FOR A RIDE"

Here we see Brother B. P. Rice, Secretary of the Southeastern Section of A. W. W. A. being "taken for a ride" during the recent meeting of the Section in Birmingham.

This "bike" plays a part in one of ACIPCO'S ceremonials and was displayed during the meeting, with a dare to any who would try it.

The ceremonial referred to is that the salesman who sends home "the big bacon" (an extra large order for pipe) is called in to headquarters and "put up in the World" by being given a ride on this hazardous contraption—a form of "decoration" we understand it to be.

We are told that this "bike" was used in the old days by the messenger taking pipe orders from the main office down to the foundry boss.

NATIONAL SEWAGE WORKS CONVENTION PLANNED FOR FALL

Chicago Selected as Location; Equipment Exhibit a Probability

During the Silver Anniversary Convention of the N. J. Sewage Works Assn., on March 22nd, at a special meeting of the Board of Control of the Sewage Works Federation, called by Chairman C. A. Emerson, a report was heard from the Convention Place Committee appointed in January to investigate the desirability of holding a Federation Convention and to recommend the most feasible time and location.

After the report was received the Board voted that Chicago be the location (headquarters hotel to be chosen later) and the time to be in the coming Fall, so as not to conflict with any convention of importance to members of the Federation.

It is the plan of the Board to hold the first convention in conjunction with the annual meeting of the Central States Sewage Works Assn.

The Board also voted to ask the Water Works Mfgrs. Assn. to arconjunction with the convention, range for an equipment exhibit in naming W. J. Orchard (member at large) to place this matter before the Manufacturers Association for consideration.

GRIT REMOVAL FROM SEWAGE*

Some Fundamental Factors in Grit Separation and Grit Chamber Design

By W A. KIVELL and N. B. LUND **
Engineers
THE DORR COMPANY, INC.
NEW YORK

IT IS our aim in this paper to offer what we believe to be pertinent considerations in grit separation, and a rational method for designing sewage grit chambers. The method advocated is based upon our own observations over a period of more than twelve years, and has been checked and re-checked in our research laboratories under controlled conditions at flows approximating those dealt with in plant operation.

We shall not discuss the need for grit chambers, because the advantages of such units in modern sewage treatment practice has already become so well recognized that grit removal is being extended even to the smaller plants, including those assumedly receiving domestic sewage only.

The purpose of this paper is to recommend basic standards of grit chamber design, as follows:

1—To fix the minimum size of grit particle to be removed.
2—To determine the appropriate dimensions of a grit chamber, based upon the settling rate of particles of such minimum size.
3—To establish a means for determining the qualities of satisfactorily washed grit.

It is our belief that if the designing engineer will follow and apply the design standards, which are developed from what is to follow, he will have every assurance that plant operating results will meet the objectives set.

The Need for Correct Specification

For twenty-five years or more the practice has generally been to design sewage grit chambers on the basis solely of velocity and detention. Research studies reported in this paper, plus critical analyses of many grit chamber installations, have led us to the conclusion that this basis of design is incorrect. Instead, we are strongly of the opinion that *area is the primary governing factor,* rather than velocity and detention.

There is, we believe, a definite need for unanimity on this matter of the importance of area and on a specification that not only takes area into consideration but also gives heed to other considerations, such as the following:

1—The subsidence chamber should be designed to collect all grit coarser than a definite size—to wit, at least that coarser than 65 mesh, and in certain cases, that coarser than 100 mesh.
2—The grit removed should be essentially free of putrescible or washable organic matter. It should contain not more than 3 per cent of such material.
3—The cleaning mechanism should deliver the grit thoroughly drained
4—of its free water, so that it may be readily handled and disposed of.
4—The chamber should be designed to handle expected flows at a minimum loss of head. And, it should operate under widely varying flows without requiring adjustments.
5—The collecting chamber should perform all functions without unsightliness, the septization of deposited solids, or the liberation of foul odors.

All of these desiderata are readily obtainable if basic, and demonstrable factors in design are followed. It remains only for the designing engineer to insist on a high level of grit-chamber operation, as has already been done in the case of other units such as sedimentation tanks, digesters, trickling filters, etc.

What Is Washed Grit?

The term "washed grit" will frequently be used in this paper. Let us, therefore, briefly consider the term, and what we consider it to mean.

A method commonly used for determining the percent putrescible or, rather, washable organic content of grit employs the so-called "Dazey Churn" test as described in Sewage Works Journal, July 1930, p. 355. This test provides a means for washing the grit sample free of sewage solids which would create a nuisance, and for determining their weight relative to the weight of the grit sample. While the "Dazey Churn" test may be subject to some criticism, the results of many tests have proved it a simple and reliable method for determining whether the grit may be safely spread above ground, or had better be buried or burned to prevent nuisance.

Samples of washed grit from 23 plants have recently been analyzed for putrescibles. Of these, 18 samples or 79% had less than 3.5% putrescibles. All of the latter were clean, odorless and entirely safe to spread on the ground surface.

The remaining five samples showed from 5 to 8.7% putrescibles. Most of these were not typical grit. While they had no odor to speak of, they contained large quantities of trash such as water logged sticks, leaves, and seeds. It is interesting to note that although one sample was apparently clean it showed 7.3% loss in weight after washing. This grit contained a large quantity of inorganic slimes. Another sample containing only 5.5% putrescibles was definitely objectionable on all counts.

The results of these tests seem to indicate that typical grit containing not over 3.5% putrescibles should be generally satisfactory for disposal around the plant. However, washed grit containing less than 1% of putrescible organics can be obtained in many instances where careful attention is given to the design and operation of grit chambers. It is expected that recommendations will soon be made for revising the "Dazey Churn" test procedure in such manner that non-putrescible organics may be accounted for separately.

Inadequacy of Rule-of-Thumb Design Methods

A common rule-of-thumb method for designing grit chambers is to provide for a 60 second detention at an average velocity in the channel of 1 foot per second at maximum flow.

* This paper was one of a group of three on the same topic presented November 29, 1939, before the Sanitation Group of the American Society of Mechanical Engineers in New York City.
** Deceased.

Usually no consideration is given to the size of grit particles to be removed, settling characteristics of the grit, or the effect of area on the efficiency of the grit chamber. Mechanisms of various kinds are used to continuously remove the deposited material, after which it is sometimes washed and sometimes not. When it is not washed, a major operating nuisance is almost invariable experienced.

Investigators * have concluded that the size of grit particles which cause the most trouble in sewage plants are those of 65 mesh (0.20 m.m.) and coarser, and that complete removal of practically all 65 mesh grit from the system is an essential objective in good grit chamber design. In some cases it is desirable to design for the removal of finer than 100 mesh. Such, for instance, is the case where aeration channels for grease removal follow the grit chambers.

A study in the field shows that few plants designed on the rule-of-thumb principle referred to above, are removing anything approaching all of the +65 mesh inorganics, not to mention the +100 mesh. This is strikingly notated in Fig. 1, where the curves plotted denote the distribution of grit sizes at 21 sewage treatment plants.

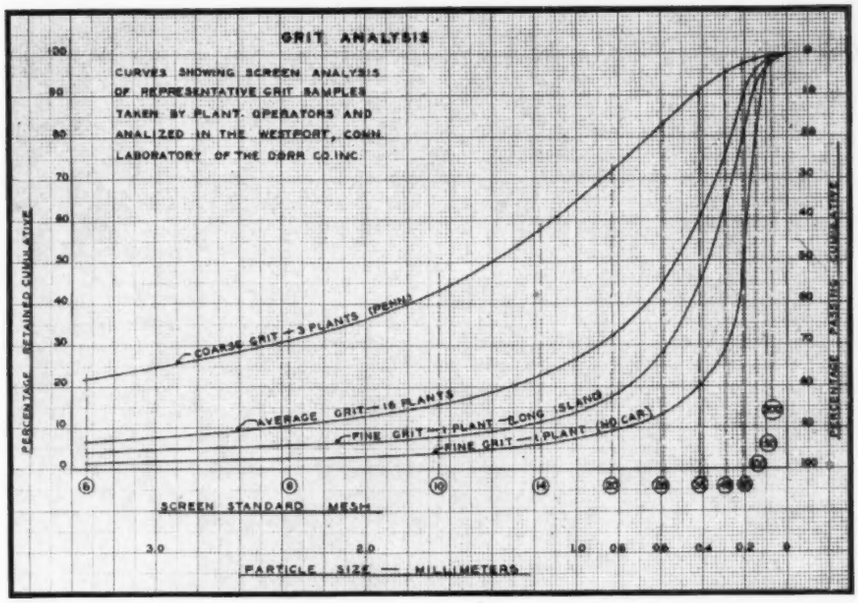

GRIT ANALYSIS
CURVES SHOWING SCREEN ANALYSIS OF REPRESENTATIVE GRIT SAMPLES TAKEN BY PLANT OPERATORS AND ANALYZED IN THE WESTPORT, CONN. LABORATORY OF THE DORR CO. INC.
COARSE GRIT — 3 PLANTS (PENN.)
AVERAGE GRIT — 18 PLANTS
FINE GRIT — 1 PLANT — LONG ISLAND
FINE GRIT — 1 PLANT (NO CAP.)
PERCENTAGE RETAINED CUMULATIVE
PERCENTAGE PASSING CUMULATIVE
SCREEN STANDARD MESH
PARTICLE SIZE — MILLIMETERS

Fig. 1—Sieve Analysis of Representative Sewage Grit From Twenty-one Plants

Starting Anew with the Old Theory of Free Settling

If, then, the rule-of-thumb method leaves much to be desired on the score of accuracy, what shall we consider as a substitute? Obviously, this is a matter of going back to fundamentals and building anew on a different basic concept. As a starter, we have taken the theory of "Free Settling" as enunciated years ago by Professor Richards, and applied successfully in other fields where fine inorganic solids suspended in water must be dealt with.

The general principles of free settling of solid particles in liquids as established by such authorities as Richards and others, state that under free settling conditions the rate of falling particles depends, other factors being equal in each case, upon:

Specific Gravity. Of two particles having different gravities, that having the higher will fall faster.

Size. Of two particles of the same specific gravity, the larger will settle faster.

The specific gravity and size have a further effect upon the rate of acceleration of the particles during the time they are acquiring their full velocity, that is, before they reach the point where the friction of the water, plus the force of the rising current, if there be any, balances the force of gravity. This effect is that, of two particles which are equal-settling, the smaller particle with higher specific gravity reaches its full velocity more quickly than the larger particle with lower specific gravity or, in other words, it has greater acceleration.

Shape. Of particles which just pass through the same screen, the round grain settles faster than the long, narrow grain, and the latter settles faster than the flat grain.

Other conditions which affect the settling of particles are air bubbles, grease, magnetic characteristics, and the density and viscosity of the liquid.

Richard's theory relates to quartz (2.65 sp. gr.) grains settling in still

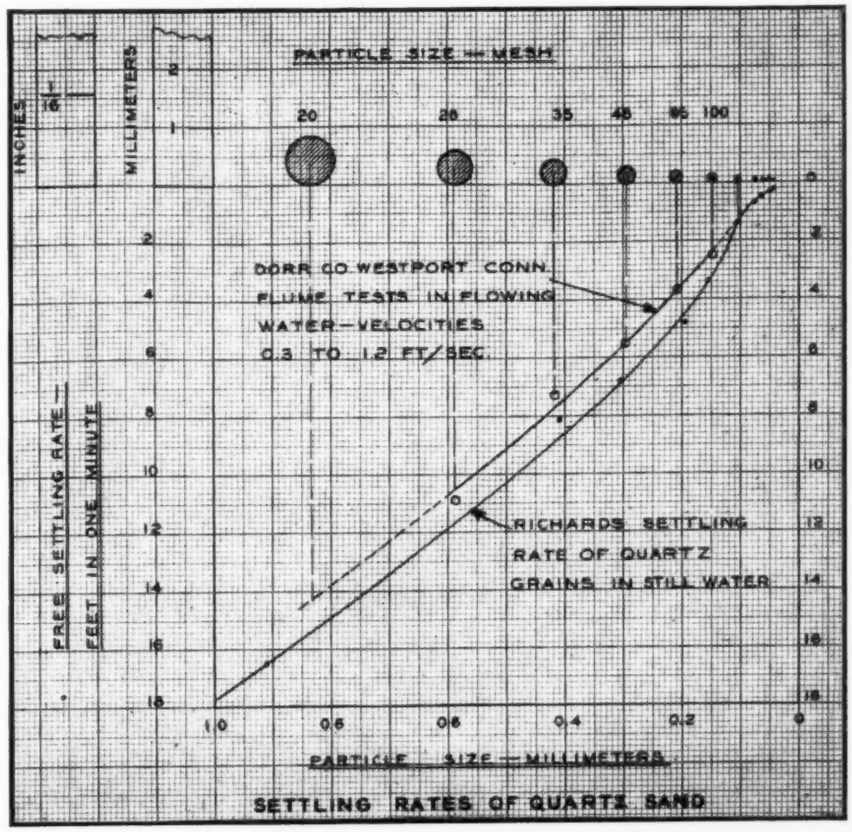

PARTICLE SIZE — MESH
INCHES
MILLIMETERS
DORR CO. WESTPORT CONN.
FLUME TESTS IN FLOWING WATER — VELOCITIES 0.3 TO 1.2 FT./SEC.
RICHARDS SETTLING RATE OF QUARTZ GRAINS IN STILL WATER
FREE SETTLING RATE — FEET IN ONE MINUTE
PARTICLE SIZE — MILLIMETERS
SETTLING RATES OF QUARTZ SAND

Fig. 2—Settling Rates of Quartz Sand Grains
Comparing Observed Rates in Still Water and in Flume Flows at Various Rates.

* A.S.C.E.-Transactions Vol. 91, p. 495 (Dec., 1927) "Grit Chamber Practice—A Symposium.")

water. Grit chamber operation deals with the settling of grains of about the same specific gravity in a stream of sewage flowing at rates from 0.3 to 1.2 feet per second. Studies made at our Westport Conn. laboratory, which will be discussed in greater detail later, indicate that similar sized particles settle according to Richard's theory, regardless of whether the water is in a quiescent state or in motion. This is clearly brought out in Fig. 2 where the two curves, representing rates of settling under the two conditions, are almost identical.

Some Deductions from Theory as Applied to Practice

Using the settling rates plotted in Fig. 2 we have made some deductions with respect to the paths traced by particles of various sizes while settling in streams of water flowing at several velocities experienced in grit chamber practice. These paths are shown graphically in Fig. 3.

The horizontal lines (depths of flow) may be taken to represent the bottoms of grit collecting tanks of various depths. The diagonal lines represent the settling paths of particles of various sizes at the indicated velocity of flow. The particle size appears on the diagonal and the velocity at the end of each line. The settling paths of 48, 65 and 100 mesh particles are shown for velocities of flow of 0.4, 0.6, 0.8 and 1 foot per second. For each of the four velocities the horizontal scale reveals the distance that a particle of given size must travel horizontally before it will have settled to the depth appearing on the left vertical scale.

Theory of Grit Chamber Design

From the foregoing we may state the following theory:

"A sand grain suspended in a liquid tends to settle at the same velocity with reference to the surrounding fluid, regardless of whether the body of liquid is at rest or is moving in a horizontal direction."

It has been determined that the size of sand particles ordinarily present in any appreciable quantity in domestic sewage lies within a range of 0.10 m.m. (150 mesh) to 0.83 m.m. (20 mesh) diameter. The settling velocities of quartz grains, within these limits, have been determined in bodies of water flowing horizontally at velocities of 0.3 to 1.25 ft. per second. At velocities above 1.25 ft. per second, the sand grains cannot come to rest on a flat surface as they are caused to slide along the bottom by the high velocity of flow. At velocities below 0.3 ft. per second, settling conditions are practically the same as in still water.

Where the stream is subjected to agitation just ahead of the grit chamber there is, of course, a certain period of time required for the grit particles to reach their terminal (maximum) settling rate, but this time element is so short that it can be negleted in practice. Once the maximum or terminal velocity of fall has been reached, settlement continues at a constant rate thereafter. Settling particles, therefore, take a diagonal path which is the resultant of the horizontal force, due to the sweeping stream, and the vertical force exerted by gravity.

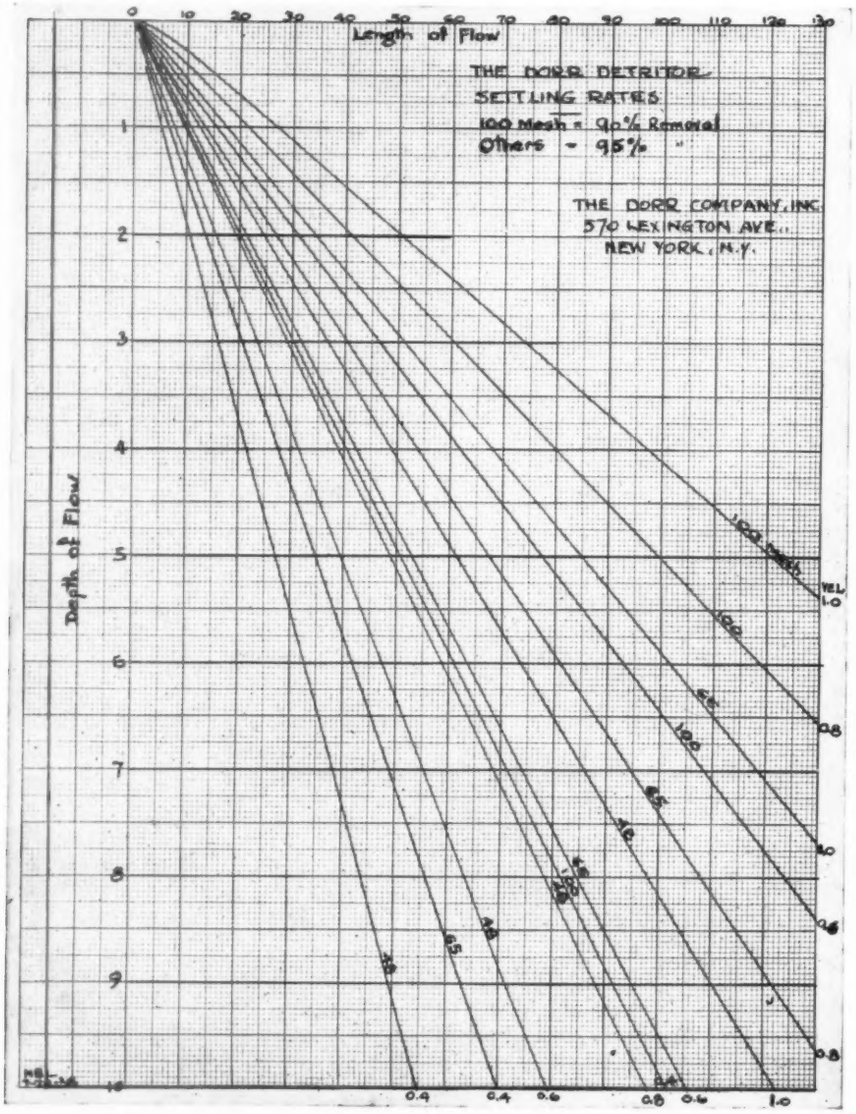


Fig. 3—Paths-of-Settling of Particles of Representative Sizes of Sewage Grit in Characteristic Grit Chamber Velocities

Application of the New Theory to Common Types of Grit Chambers

Let us now see what happens in the usual types of grit chambers according to the new theory which we have just deduced.

Referring to Fig. 4, the diagonal line represents the path of a 65 mesh particle of quartz under the influence of a velocity of stream at 1 ft. per second and a detention period of 60 seconds.

In most cases there will be turbulence in the influent channel so that the dispersion of sand grains throughout the liquid will extend from practically the surface to the floor of the channel. This applies particularly to the finer material, such as 65 and 100 mesh. If we start by assuming that all 65-mesh particles enter the subsidence chamber at the water surface, we are looking to securing the most conservative design, and, thereby, the minimum number of such particles reaching the outflow end of the chamber.

Diagrammatic outlines of the floor levels of grit chambers of varying depths are shown by F, G, H, I and J. All of these grit channels of trial

design are 60 ft. long and in each case it must be assumed the width of the tank is to be adjusted to provide a stream velocity of 1 ft. per second for the indicated depths on the study-graph. For the purpose of illustration we will assume that the designed flow is 11.0 m.g.d. (17 c.f.s).

Following the diagonal path of settling line it is revealed that tanks F and G would be longer than necessary to remove the 65-mesh grit. In I and J, the 65-mesh particles entering at the surface would not reach the bottom within the tank bounds. It will be readily seen that this condition is aggravated as tank depth is increased. In H, the end of the tank and the floor of the tank both intersect the diagonal settling path, indicating that 3 ft. 6 in. depth is correct for this flow.

From this base the necessary tank width is calculated. By referring to the table in the upper right-hand corner, the width of this 60 ft. tank is 4 ft. 10 in. and the area of Tank H is 291 sq. ft. That the area is an important consideration becomes apparent later.

This diagrammatic presentation shows that the "1 ft. per second—60 seconds detention" method for designing grit chambers has definite limitations. No satisfactory design can be established without first considering the settling rate of the *minimum* particle size to be removed.

Fig. 5 is similar to Fig. 4 insofar as the basic conditions of particle size, rate of flow and detention are concerned. All the grit chambers tabulated in the upper right-hand corner have one characteristic in common—the same surface area of 289 sq. ft.—while the common characteristics of those tabulated in Fig. 4 was length, 60 ft. The longitudinal cross-sections, lettered A, B, C, D and E, are shown of the correct lengths for individual depths, from 1 to 5 ft. inclusive.

Note the correlation between Figs. 4 and 5. In Fig. 4 the surface area of the correctly designed tank "H" was 291 sq. ft.; in Fig. 5 it proves to be 289 sq. ft. Apparently, then, surface area is a vitally important consideration in correct grit chamber design.

Area the Determining Factor in Design

In order to check our hypothesis with respect to the importance of surface area, another relationship has been drawn up in Fig. 6. The graph is similar to Fig. 5 with the exception that the particle settling path is in a stream having a velocity of 0.6 ft. per second rather than 1 ft. per second. In this case the tank widths have been re-adjusted to provide a cross-section area which will give 0.6 ft. per second for the varying depths shown.

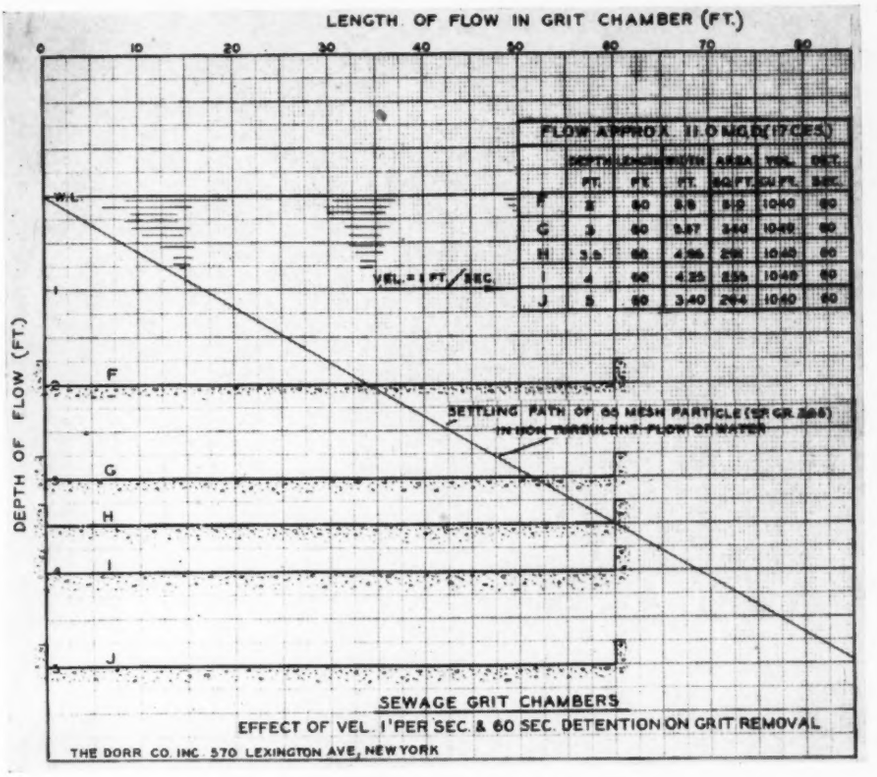

LENGTH OF FLOW IN GRIT CHAMBER (FT.)
0 10 20 30 40 50 60 70 80
FLOW APPROX. 11.0 M.G.D. (17 C.F.S.)
DEPTH FT. | LENGTH FT. | WIDTH FT. | AREA SQ.FT. | VOL. CU.FT. | DET. SEC.
F 3 60 5.16 310 1040 60
G 3 60 5.87 360 1040 60
H 3.5 60 4.96 298 1040 60
I 4 60 4.25 256 1040 60
J 5 60 3.40 204 1040 60
W.L.
VEL. = 1 FT./SEC.
DEPTH OF FLOW (FT.)
F
G
H
I
J
SETTLING PATH OF 65 MESH PARTICLE (SP GR 2.65) IN NON TURBULENT FLOW OF WATER
SEWAGE GRIT CHAMBERS
EFFECT OF VEL. 1' PER SEC. & 60 SEC. DETENTION ON GRIT REMOVAL
THE DORR CO. INC. 570 LEXINGTON AVE. NEW YORK

Fig. 4—Chamber Design—Study No. 1

Observing the path of 65 mesh grit through chambers having a common length but various combinations of width and depth to secure a common detention of 60 seconds at a velocity of 1 ft./sec. in all five designs. Thus revealed is the high importance of surface area in contrast with cross sectional area, or velocity.

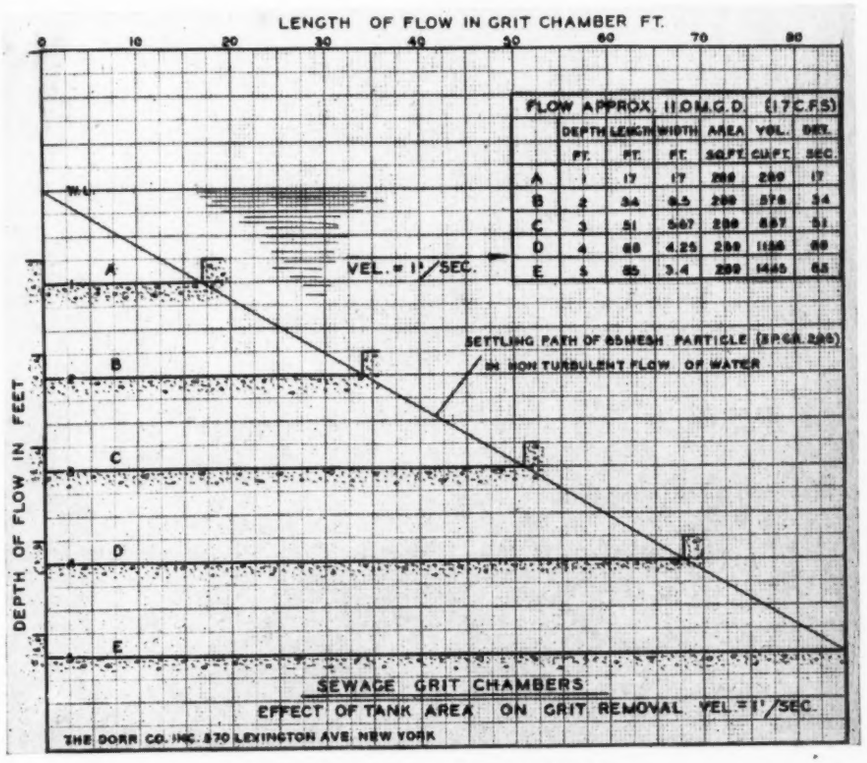

LENGTH OF FLOW IN GRIT CHAMBER FT.
0 10 20 30 40 50 60 70 80
FLOW APPROX. 11.0 M.G.D. (17 C.F.S.)
DEPTH FT. | LENGTH FT. | WIDTH FT. | AREA SQ.FT. | VOL. CU.FT. | DET. SEC.
A 1 17 17 289 289 17
B 2 34 8.5 289 578 34
C 3 51 5.67 289 867 51
D 4 68 4.25 289 1156 68
E 5 85 3.4 289 1445 85
W.L.
VEL. = 1'/SEC.
DEPTH OF FLOW IN FEET
A
B
C
D
E
SETTLING PATH OF 65 MESH PARTICLE (SP GR 2.65) IN NON TURBULENT FLOW OF WATER
SEWAGE GRIT CHAMBERS
EFFECT OF TANK AREA ON GRIT REMOVAL VEL. = 1'/SEC.
THE DORR CO. INC. 570 LEXINGTON AVE. NEW YORK

Fig. 5—Chamber Design—Study No. 2

In which the factors in common for the 5 chambers are surface area and the 1 ft./sec. velocity of flow. Taken with Fig. 4 this graphical study also reveals the high significance of surface area in contrast with other dimensions.

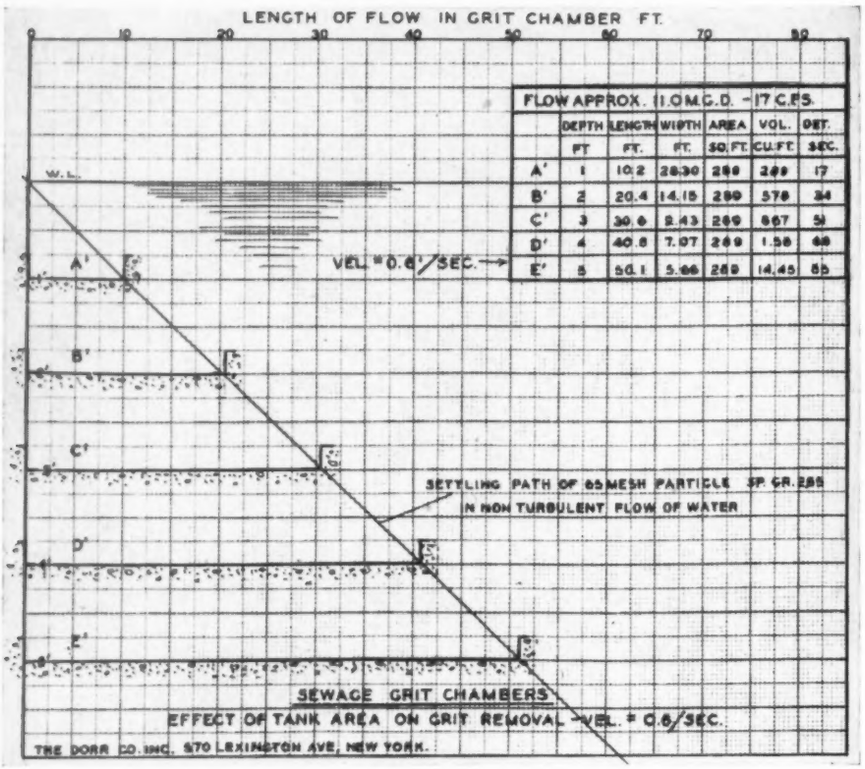

LENGTH OF FLOW IN GRIT CHAMBER FT.
0 10 20 30 40 50 60 70 80
FLOW APPROX. 11.0 M.G.D. - 17 C.F.S.
DEPTH FT
LENGTH FT.
WIDTH FT.
AREA SQ. FT.
VOL. CU. FT.
DET. SEC.
A' 1 10.2 28.30 289 289 17
B' 2 20.4 14.15 289 578 34
C' 3 30.6 9.43 289 867 51
D' 4 40.8 7.07 289 1.156 68
E' 5 50.1 5.66 289 14.45 85
W.L.
VEL. = 0.6'/SEC.
SETTLING PATH OF 65 MESH PARTICLE SP. GR. 2.65 IN NON TURBULENT FLOW OF WATER
SEWAGE GRIT CHAMBERS
EFFECT OF TANK AREA ON GRIT REMOVAL - VEL. = 0.6/SEC.
THE DORR CO. INC. 570 LEXINGTON AVE, NEW YORK.

Fig. 6—Chamber Design—Study No. 3

Here the same common surface area, that proven the correct selection in Figs. 4 and 5, is employed in studying the effect of 0.6 ft./sec. velocity on the settling path of 65 mesh particles.

The areas, 289 sq. ft., indicated in the table in the upper right-hand corner are the same as those for velocities of 1 ft. per second in Fig 5 and for curve "H" in Fig. 4.

The fact that the diagonal path which a particle follows is a straight line is of considerable significance. It means that if the velocity is halved, the particle will settle out in half the distance, so, with a tank one-half the depth and width sufficient to secure one-half the velocity, the particle will settle out in half the distance. With these facts established, it may be stated:

"The capacity of a grit chamber is in direct proportion to the area, regardless of the relation of width, depth, and velocity."

This statement is based on the assumption that the chamber in question is of rectangular shape and that the velocity of flow is uniform. The truth of the above statement can best be proven mathematically as follows:

Let:

F = Flow in cu. ft./second.
Q = " " M.G.D.
W = Width of channel in ft.
L = Length of channel in ft.
D = Depth of channel in ft.
V = Velocity of stream in ft./sec.
X = Settling rate of particle in sec./ft.
A = Surface area of channel in sq. ft.

Then

$$F = WDV \quad (1)$$

$$D = \frac{L}{VX} \quad (2)$$

$$A = WL \quad (3)$$

$$F = 1.5Q \quad (4)$$

Substituting (2) in (1)

$$F = \frac{WVL}{VX} \text{ or } F = \frac{WL}{X} \quad (5)$$

Substituting (3) in (5)

$$F = \frac{A}{X} \text{ or } A = FX \quad (6)$$

Substituting (4) in (6)

$$A = 1.50QX \quad (7)$$

Therefore, the area required per MGD is

$$A = 1.5X \quad (8)$$

or the area required per cu. ft./sec.

$$A = X \quad (9)$$

Derived from the above are:

Given length and velocity to figure depth

$$D = \frac{L}{VX} \quad (10)$$

Given depth and velocity to figure length

$$L = DXV \quad (11)$$

Given length and depth to figure velocity

$$V = \frac{L}{DX} \quad (12)$$

Given width to figure length

$$L = \frac{A}{W} \quad (13)$$

Given length to figure width

$$W = \frac{A}{L} \quad (14)$$

It will be seen that in (5) the velocities cancel out, leaving the capacity a function solely of width and length or area and settling rate of particle. For these reasons a *grit chamber may be made of any shape desired,* so long as the area is sufficient. Having established area as the determining factor in the design of sewage grit chambers, the maximum overflow rates for practically complete removal of various size particles may now be tabulated.

Mesh	Overflow Rate*
35	73,000
48	51,000
65	38,000
100	25,000

(*Gals./day/sq. ft. area)

For example, a flow of 11 m.g.d. would require a grit chamber surface area of $\frac{11{,}000{,}000}{38{,}000} = 289$ sq. ft. in order to remove practically all 65 mesh and coarser grit.

Relation of Particle Size to Settling Area of Five Grit Chambers in Operation

In order to illustrate the relationship of settling area to particle size, we will refer to results derived from operating data from three representative grit chambers designed on the old basis of velocity and detention alone. The particle sizes retained and the sizes passing through agree with our area-capacity relationship. We shall also comment on two grit chambers having design features of special interest.

Early Type of Grit Chamber

The first is an early single channel grit chamber designed to handle a maximum flow of 25 m.g.d. in each channel. Present storm flows are reported to be 14 to 28 m.g.d. The channel, according to our claims, should be deficient in settling area since a consideration of length and depth indicates it capable of removing only coarse grit, 48 mesh and larger, even at velocity of 0.7 ft. per second.

Under the heading Grit Chamber "A," is a typical screen analysis of grit removed by this chamber, as supplied us by the plant operator. Note that 96% of the particles collected were retained on a 50-mesh screen. Deposits of fine grit appear in the primary sludge and digesters.

More Recent Type Chamber

The second unit is a twin-channel chamber in a recently constructed

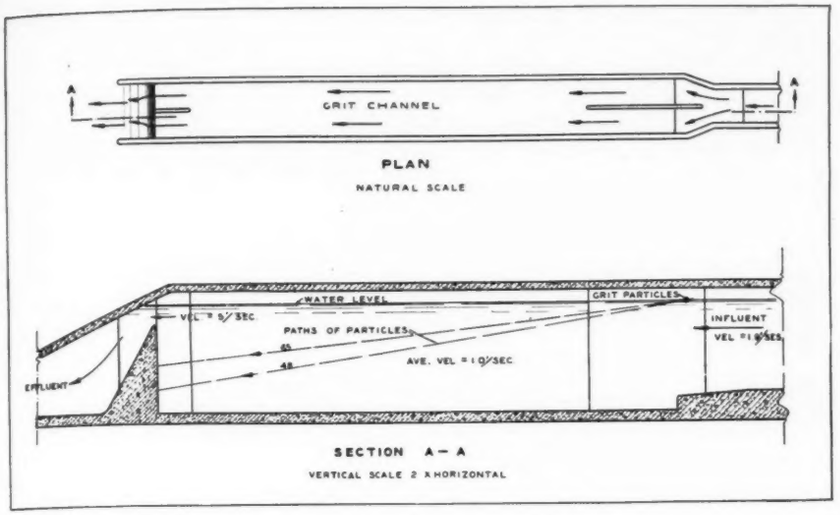


Fig. 7—Deep Weir-Wall Type of Chamber

This diagram indicates the lack of value of great depth in retention of grit of 65 mesh and finer when the velocity is 1 ft./sec. The settling area proves to be deficient.

plant. Each channel is designed for a maximum flow of 40 m.g.d. Effluent connections are fitted with adjustable gates which operate as submerged weirs.

The channels are deficient in settling area and operated at a velocity of 1.25 ft./sec. are capable of removing only coarse grit coarser than 48 mesh particles. As a result grit deposits in the digesters are marked. Under heading Grit Chamber "B" appear a typical screen analysis of grit taken from the digesters.

Double Channel Chamber

The third unit is a multiple channel chamber, each channel being designed to handle a constant flow of 90 to 100 m.g.d. received from raw sewage pumps. The chamber discharge is through large submerged gated openings.

These channels have a settling area capable of removing coarse grit up to and including a portion of the 48-mesh particles at velocities between 0.75 and 1.05 ft./sec. Considerable fine grit has been found in the plant beyond the grit chambers. According to analysis of the grit that passes the grit chambers, 80% is between 40 and 80 mesh. See analysis under heading Grit Chamber "C."

Grit Chamber "A"
(Vel. = 0.7 ft./sec.)

Typical Sieve Analysis of Grit Deposited

Through 30	56%
Through 30 / On 50	40%
Through 50 / On 60	3%
Through 60 / On 150	1%
Volatiles (dry basis)	10.2%
Putrescibles	0.8%

Grit Chamber "B"
(Vel. = 1.25 ft./sec.)

Sieve Analysis of Grit Taken from Bottom of Sludge Digestor

On 28	6.2%
Through 28 / On 48	54.0%
Through 48 / On 100	23.0%
Through 100	10.0%

Grit Chamber "C"
(Vel. = 0.75 to 1.05 ft./sec.)

Sieve Analysis of Typical Grit

(a) Retained in Chamber.

On 5	20.5%
Through 5 / On 10	15.0%
Through 10 / On 20	24.5%
Through 20 / On 40	25.0%
Through 40 / On 60	10.5%
Through 60	4.5%

(b) Passing Through Chamber.

On 20	1.4%
Through 20 / On 40	2.3%
Through 40 / On 60	9.4%
Through 60	86.6%

Deep Weir Wall Type

Following the same procedure as in the three cases above we have made a diagrammatic analysis of a grit chamber designed to handle 160 m.g.d. constant flow, received from raw sewage pumps—See Fig. 7. The design is interesting because of the unusual water depth and the use of a deep weir wall at the discharge end.

The diagram indicates that at a velocity of flow of 1 ft./sec. these channels have a settling area capable of removing only the coarse grit, 35 mesh and larger and, possibly, a portion of the 48 mesh grit.

Since capacity of grit chambers is a function of surface area, the extra depth is of no value. The deep pocket formed at the weir wall might even prove a handicap. To date no operating data has become available to confirm our conclusions based on the graphic analysis.

Although the line of settling of 65-mesh grit strikes the end wall, we are of the opinion that a great deal of the grit will be carried up and over the wall, due to the upward current caused by interception of the main flow. It will be interesting to observe whether or not coarse grit tends to pocket at the weir wall and, further, whether or not the extra depth adds to the sewage solids to be washed from the grit collected.

Proportional Weir Type

Another recently built unit (Fig. 8) makes use of a proportional weir at the discharge end of the channels to automatically control velocity of flow. The attempt of the engineer is to prevent desposition of sewage solids by holding the velocity of flow at about 1 ft. per second, while the depth of flow may vary. There are a number of points about this design that are of interest. We find the settling area to be sufficient to remove coarse grit, 48 mesh and larger, assuming uniform flow conditions through the channel.

In the diagram, lines of settling have been drawn for a 65 and 48-mesh grit particle located near the water surface at the entrance end of the channel. Because the chamber is deficient in settling area, the normal path of 65-mesh particles does not intersect the bottom. The normal path of the 48-mesh particle does intersect near the discharge end; but what effect the proportional weir may have on the ability of the particle to drop out of the line of converging flow to the weir is something of a question.

Velocity of flow at entrance to the chamber is 4 ft. per second. Computed average velocity within the chamber is assumed to be 1 ft. per second. Velocity of discharge through the wide bottom slot of the proportional weir can be computed at 16 ft./sec. What the actual velocity of flow conditions are near the bottom of the main chamber due to influences of these control features, remain problematical.

Scale model studies in our hydraulic laboratory at Westport have shown that after an hydraulic balance is established, flow velocities persist throughout the liquid even though the total energy of flow may be computed to be quite insignificant.

We have noted the persistence of flow in large settling tanks, even where very low velocities are involved. The reader has probably seen the movement of underwater cloud banks of activated sludge or chemical floc in settling tanks. With these observations in mind, we wonder if the proportional weir instead of lending to the efficiency of channels for collection of grit, does not actually reduce the effective area and would be better out than in.

Flume Tests to Determine New Design Factor

While much had been published on the settling rates of various substances in quiscent liquids, there was very little information available on the settling characteristics of free falling materials in flowing streams. In consequence, a series of flume tests was begun at our Westport laboratory in order to secure basic design data under actual large-scale flow conditions.

The flume was built with an intake from a river and was equipped with a baffled stilling box at the head end. The flume was 45 ft. total length, 41 in. total depth, by 17½ in. width inside. It was equipped with an adjustable rectangular weir at the downstream end. To prevent eddy currents, the bottom of the flume was divided into sections 5 ft. long by installing thin riffles, wedge-shaped in cross-section. Each riffle section had a plugged drain hole, the entire flume being built of finished tongue and groove lumber.

Carefully weighted, uniform samples of wet sand were gently sifted into the head end of the flume at the water surface in a manner to prevent plunging. After a time of such application, the flume was slowly drained and the deposit from each of the 5 ft. sections was carefully removed. Recovered sand was dried and screen analyses made to determine the size and quantities of sand recovered at various distances from the inlet, as the result of varying velocities and depths of flow.

Thirty-five such tests were made, with nine samples of recovered sand from each test put through a screen analysis. Velocities ranged from .25 ft. per second to 1.15 ft. per second; weir settings from 6½ to 31 inches in height; and flow depths from 1 ft. to 3 ft., at 6-inch intervals. Such range was considered to cover the practical limits.

The results of these tests confirmed the assumptions, made earlier in this paper, concerning the most likely path of a sand particle of given size in a stream of moving water. Furthermore, and of equal importance, these tests confirmed our theory that surface area constitutes the all important consideration and yielded a wealth of data for the correct design of what, at the time, constituted an entirely new type of grit chamber.

Continuous Removal and Washing

We may now assume that on the basis of the foregoing, we can design a grit chamber which, if continuously cleaned, will remove, within the per-

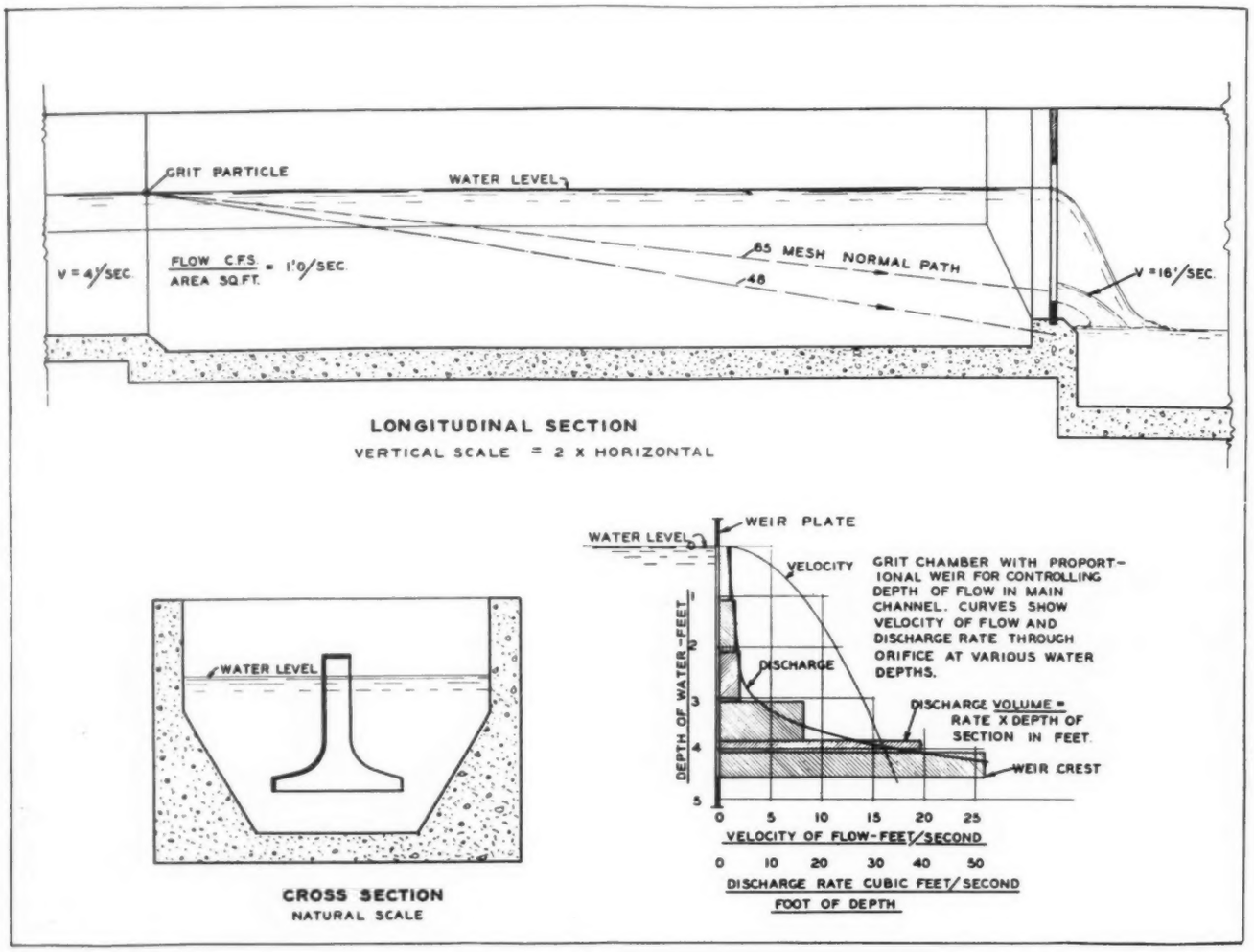

GRIT PARTICLE
WATER LEVEL
V = 4'/SEC.
FLOW C.F.S. / AREA SQ.FT. = 1'0/SEC.
65 MESH NORMAL PATH
48
V = 16'/SEC.
LONGITUDINAL SECTION
VERTICAL SCALE = 2 X HORIZONTAL
WATER LEVEL
CROSS SECTION
NATURAL SCALE
WEIR PLATE
WATER LEVEL
VELOCITY
DISCHARGE
DEPTH OF WATER-FEET
GRIT CHAMBER WITH PROPORTIONAL WEIR FOR CONTROLLING DEPTH OF FLOW IN MAIN CHANNEL. CURVES SHOW VELOCITY OF FLOW AND DISCHARGE RATE THROUGH ORIFICE AT VARIOUS WATER DEPTHS.
DISCHARGE VOLUME = RATE X DEPTH OF SECTION IN FEET
WEIR CREST
0 5 10 15 20 25
VELOCITY OF FLOW-FEET/SECOND
0 10 20 30 40 50
DISCHARGE RATE CUBIC FEET/SECOND FOOT OF DEPTH

Fig. 8—Recent Chamber Design Employing Proportional Weir

Even though the design maintains a velocity of 1 ft./sec. satisfactorily, applying the settling path of 48 and 65 mesh grit reveals a lack of sufficient settling area for retention of 65 mesh grit and finer. How much 48 mesh grit will be retained is problematical.

OPERATING DATA—DETRITOR INSTALLATIONS—WASHED GRIT

LOCATION	M.G.D. Flow Aver.	M.G.D. Max. Storm	DETRITOR Feet Square	DETRITOR Max. Water Depth	GRIT (Cubic Yards) Av. Per Day	GRIT (Cubic Yards) Max. Per Day	GRIT (Cubic Yards) Max. Per M.G.	WASHED GRIT 10	20	35	48	65	100	150	% Putres. (Dry Basis)	% Volatiles in Putres.	Odor
Austin, Tex.	2.0	4.5	18′	3′6″	0.12			9.3	26.1	59.8	76.3	91.0	97.6	99.2	0.85	29.0	None
Baltimore, Md. ..	81.52	243	50′	6′4.25″	16.2	45	0.54	6.7	17.7	42.6	66.1	88.0	97.4	99.5	3.1	56.0	Slight
Barrington, Ill. ..			10′	1′3″													
Battle Creek, Mich.	5.8	8.6	26′	2′6″	4	54	6.30	44.2	81.9	93.5	95.5	97.4	98.8	99.4	2.1	54.1	None
Beacon, N. Y.....	0.635	0.97	10′	1′5″	.074	.67	0.69	20.7	34.0	54.5	69.8	87.7	95.0	98.0	3.3	61.8	Slight
Berea, Ohio	0.400	2.00	10′	1′9.5″	1	1.5	0.75	58.5	83.1	93.0	95.2	97.0	97.3	97.5	4.6	50.4	Musty
Birmingham, Ala.	8.71	16.0	22′	2′9″	0.24	0.48	0.03	31.4	52.9	79.6	89.6	95.3	97.5	98.6	3.5	46.4	None
Cedar Rapids, Ia..			22′	2′6″				2.1	5.7	15.0	26.0	48.9	71.2	81.5			
Cleveland, Ohio (East)	80.0	92.0	40′	3′10.25″	1.0		20.0	13.5	26.4	63.3	89.5	94.0	97.6	98.0	1.4	48.8	None
Cleveland, Ohio (West)	15.16	23-25	35′	2′6″	.77			14.7	23.7	47.7	70.6	90.0	97.6	99.5	0.95	19.0	None
Colo. Springs, Colo.	4.67		18′	2′0″				23.3	52.2	89.0	97.6	99.3	99.6	99.8	0.4	49.5	None
DePere, Wis.	0.476	2.285	10′	1′6″	150 lbs.	1368 lbs.	0.20	20.9	39.0	57.7	69.0	81.5	91.0	95.0	7.3	24.0	Musty
Dixon, Ill.	0.72	2.00	10′	1′3.75″				20.9	36.7	81.2	92.7	95.5	95.6	96.0	5.5	67.1	Foul
Duluth, Minn.			26′	2′9″				11.7	34.5	65.5	81.2	92.1	97.4	99.4	1.72	37.1	None
Elmhurst, Ill.	1.5	2.5	14′	1′9″				13.6	35.5	67.6	84.3	94.6	98.5	99.0	1.5	42.5	Musty
Fargo, N. D.....	2.0		14′	2′0″	0.15			32.1	54.7	74.4	82.0	89.2	94.7	98.4	8.7	62.9	None
Farrel, Pa.			10′	1′6″													
Findlay, Ohio	2.0	10.0	20′	2′0″	0.09	0.27	0.03	32.8	58.1	79.1	88.8	95.5	98.1	99.2	2.6	69.2	Slight
Ft. Dodge, Ia.....	1.8	3.0	12′	1′4.5″	0.22	0.37	0.12	51.7	74.8	84.4	86.2	88.6	93.8	98.7	2.4	85.7	None
Green Bay, Wis...	5.0	20.0	26′	3′0″	1.30	5.60	0.28	3.7	9.1	19.8	29.6	51.7	78.2	96.1	1.23	43.5	None
Greensboro, N. C..	5.2	15.0	14′	2′2″	0.12												
Houston, Tex.			26′	2′8.5″													
Jeanette, Pa.	0.9	1.5	10′	1′6″	0.19	0.45	0.30	55.5	84.6	97.3	98.3	98.4	98.6	98.7	2.30	71.5	None
Klamath Falls, Ore.	2.0	4.0	12′	2′6″	0.19			32.8	65.5	80.1	83.1	85.4	87.5	90.5	12.5	79.2	Slight
Kokomo, Ind.	2.82	4.35	15′	1′6″	0.15	1.60	0.37	13.0	24.8	50.2	68.0	87.1	95.9	99.0	0.8	23.0	None
La Crosse, Wis...	5.20	12.0	26′	2′6″	0.56	2.50	0.21	10.8	24.4	40.8	62.4	86.4	97.5	99.2	0.8	70.6	None
Lansdale, Pa.			10′	2′8″													
Muskegon, Mich...	4.0	10.0	20′	1′7″	0.22	3.00	0.30	9.4	14.9	38.0	69.1	92.2	98.8	99.0	0.6	55.5	None
Norwalk, Ohio ...			10′	1′9″													
Phoenix, Ariz. ...	13.0	20.0	60′	4′0″	0.28			17.0	42.7	80.7	91.2	96.0	97.5	98.1	2.2	40.3	Musty
Pottstown, Pa. ...	1.0	5.0	11′	2′4″	None	0.26	0.05	27.0	54.4	81.6	90.4	95.5	97.8	98.7	3.25	50.0	None
Rockford, Ill.	9.82	17.25	24′	3′1.25″	2.4	10.2	0.59	22.4	40.5	73.5	91.1	97.6	99.0	99.5	0.9	57.8	Musty
Seattle, Wash. ...			15′	2′5.5″													
Sioux Falls, S. D..	2.30	9.00	14′	2′6″	1.4	5.0	0.55	5.0	18.4	62.9	84.4	95.2	98.5	99.3	0.37	63.0	None
Souderton, Pa. ...	0.23	0.80	10′	1′6.75″	None	1.20	0.67	56.5	76.4	94.2	97.5	98.5	99.0	99.2	1.23	19.0	None
So. Milwaukee, Wis.			10′	2′6″													
Springfield, O. ...	14.0	28.0	28′	2′9″	1.1	6.0	0.24	26.0	48.0	73.9	86.0	95.8	98.4	99.0	1.6	40.0	Slight
Stockton, Colo. ...			15′	2′5.5″													
Toledo, Ohio	30.0	100.0	40′	5′0″				65.2	92.0	95.7	98.4	98.5	98.6	99.0	1.35	60.0	None
Va. B'ch, Va.....	0.35	2.0	10′	2′0″	0.03	0.56	0.28	16.5	25.9	40.6	65.0	89.0	97.6	99.0	6.0	64.3	Musty
Uniontown, Pa. ..								22.7	36.9	56.4	60.5	80.0	92.0	97.5	1.8	23.5	None

missible velocities, all grit which might cause trouble in the plant. The usual practice, even in large sewage plants, is to use as few units as may be permissible.

Grit collecting units are designed for maximum flow conditions and almost universally to provide velocity not exceeding 1 ft. per second. During dry-weather flows there is a possibility that the velocity in the chamber may drop to as low as 0.2 ft. per second or even less, at which velocity quantities of organic materials will be deposited with the grit and removed by the collecting mechanisms. If no washing step is introduced before the accumulation is discharged by the collecting mechanism, the product will run high in organic and putrescible material, so that the mixture must be disposed of immediately to prevent nuisance. However, where grit is washed and well drained it can be used on roads and paths, on sand drying beds and for other purposes around the plant, without danger of creating a nuisance.

From the foregoing it is apparent that more than mere tank design should be considered. In addition to the all important size and shape relationships, consideration in modern design is being increasingly given to providing positive, continuous mechanical facilities for removing and washing the deposited grit, thereby lessening the need for maintaining exact velocities in grit separation units, and in precluding nuisance.

The Dorr Detritor

The Dorr Detritor (Fig. 10)) was an outgrowth of our investigations. In reality the detritor is a process rather than a single mechanism. The

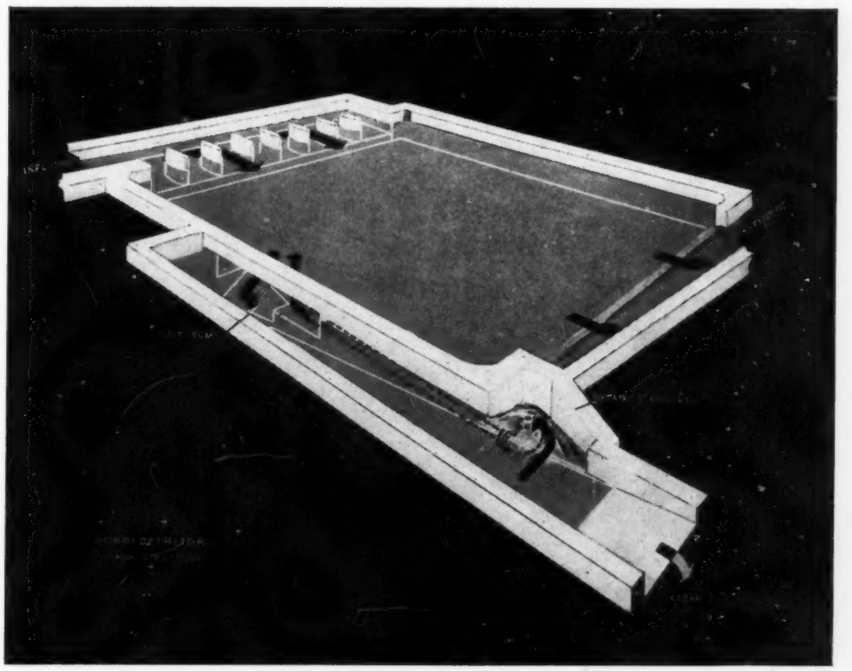


Fig. 9—The Separating Tank of the Detritor

Pictured without the collection and grit washing mechanism to emphasize area-depth relationships which have proven correct in practice—see accompanying tabulated plant operating data.

separatory tank, without mechanism, is pictured in Fig. 9 to indicate the various operations more clearly. Be cause of the demonstrated importance of surface area, the tank has been made square in design and as shallow as permissible to safety deal with all flows. Influent enters through a series of guide vanes (on left), which may be adjusted to secure the most efficient distribution for the flows prevailing and those reached in later years. The sewage flows across the tank and over the low weir (right) to the effluent channel. All solids which settle on the floor of the tank are conveyed by a revolving and oscillating collecting mechanism to a grit sump.

The cleaning channel, which is adjacent to the collecting tank, is rectangular in plan and has a sloping bottom which extends from the grit sump to a point several feet above the "short line" at maximum high-water level. The cleaning mechanism has a reciprocating rake motion which conveys the settled material from the grit sump up the slope. (See Fig. 10.)

The reciprocating rakes serve to create turbulence which throws light organic materials into supension as the rakes move the grit up the slope. As the material being raked approaches the "shore line" (water surface), a transverse flow of effluent. entering between the rakes and above the travelling layer of grit, furthers the transfer of the rejected organic material to one side while the grit is undergoing cleansing while it travels by back and fill motion gradually up the submerged slope.

The transverse flow is assisted by a specially designed non-clogging centrifugal type pump which takes away the dirty water and discharges it into the collectng tank, where it joins the flow toward the effluent weir.

The emerging washed grit is raked up the slope above water level. Here, all free water drains back and at the upper end of the slope the washed and drained grit falls into a suitable receiver.

The wash water employed consists solely of screened sewage.

The studies reported in this paper

FIGURE 17

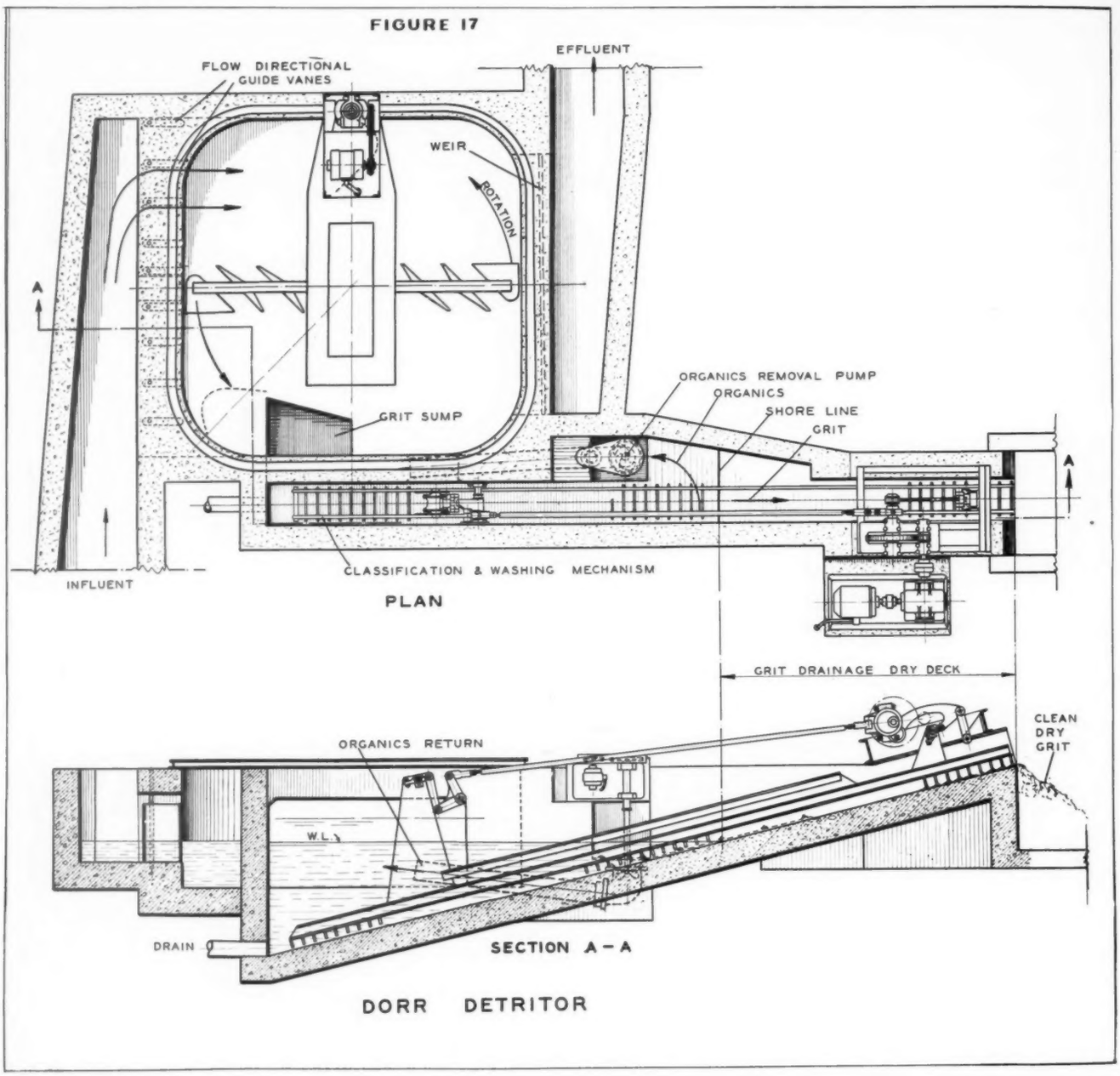
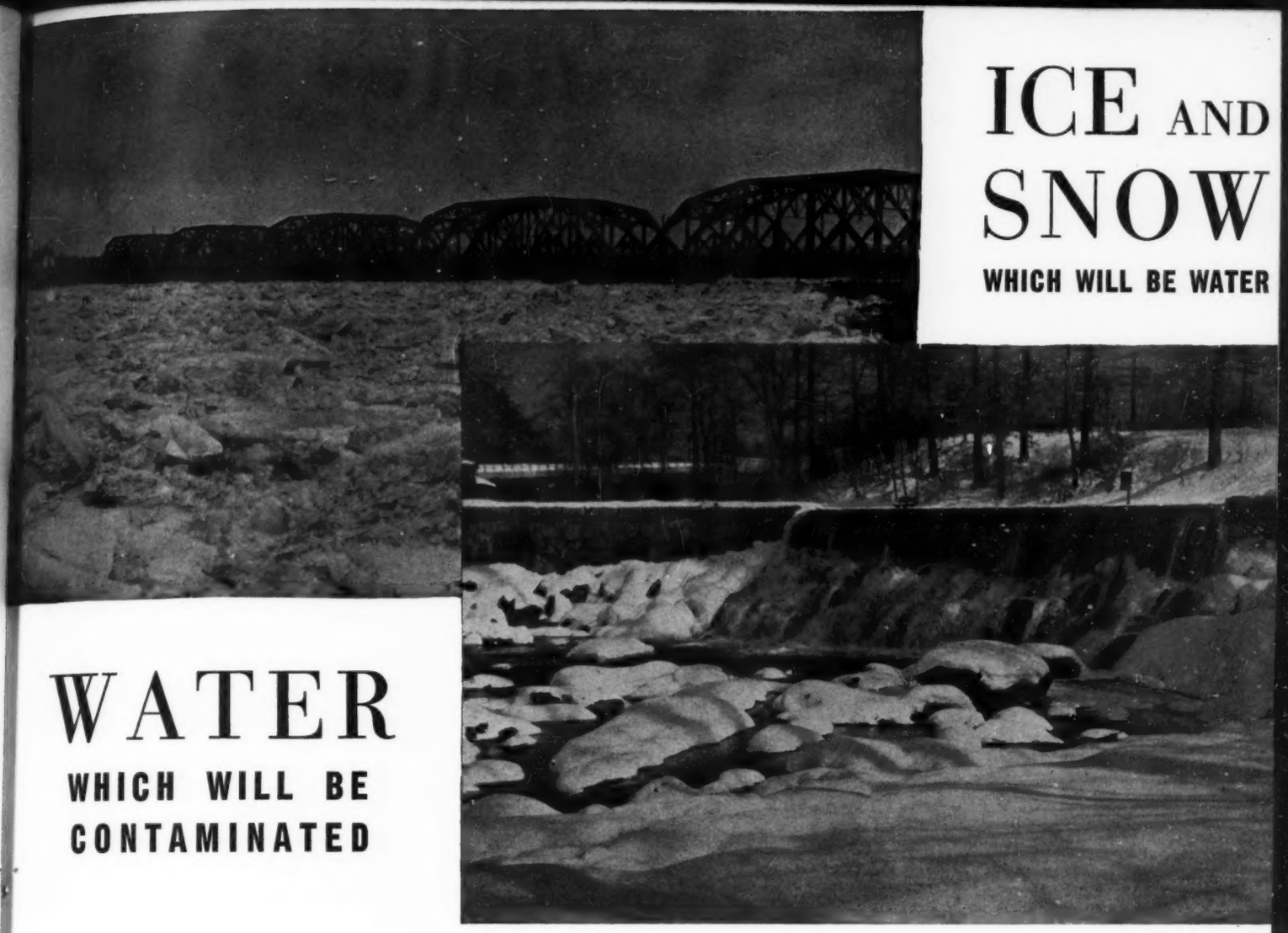


Fig. 10—The Dorr Detritor



ICE AND SNOW

WHICH WILL BE WATER

WATER

WHICH WILL BE CONTAMINATED

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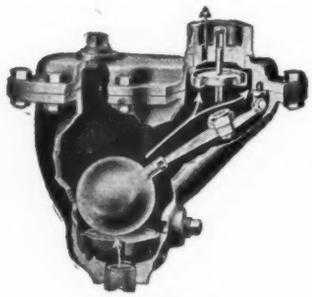

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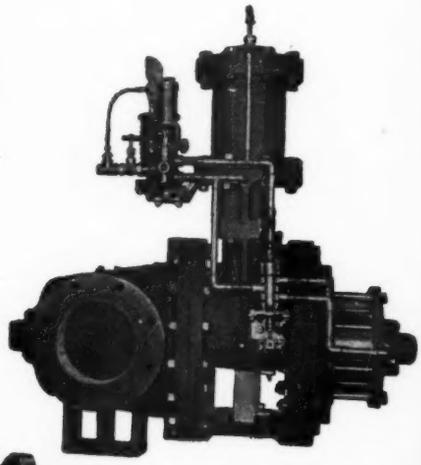

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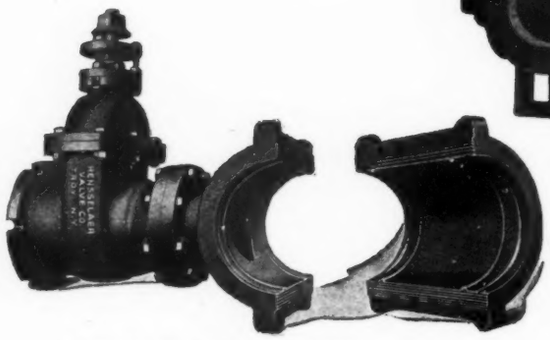

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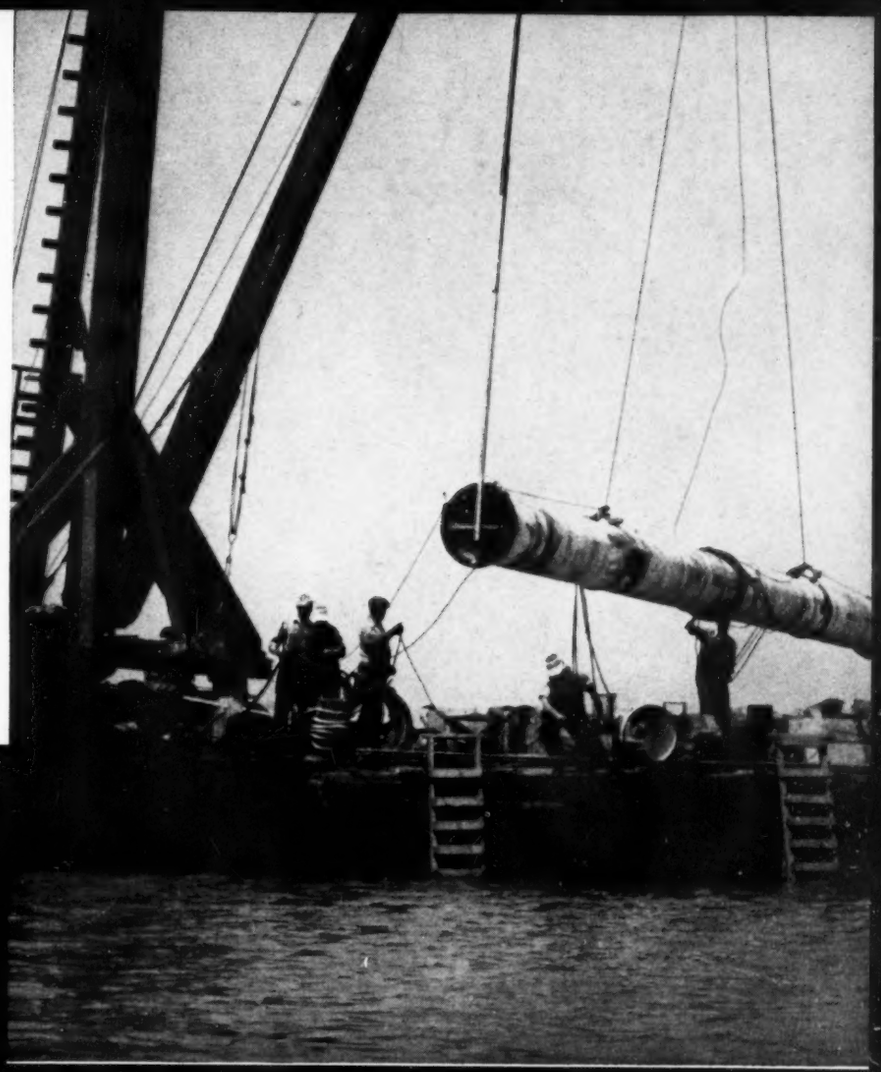

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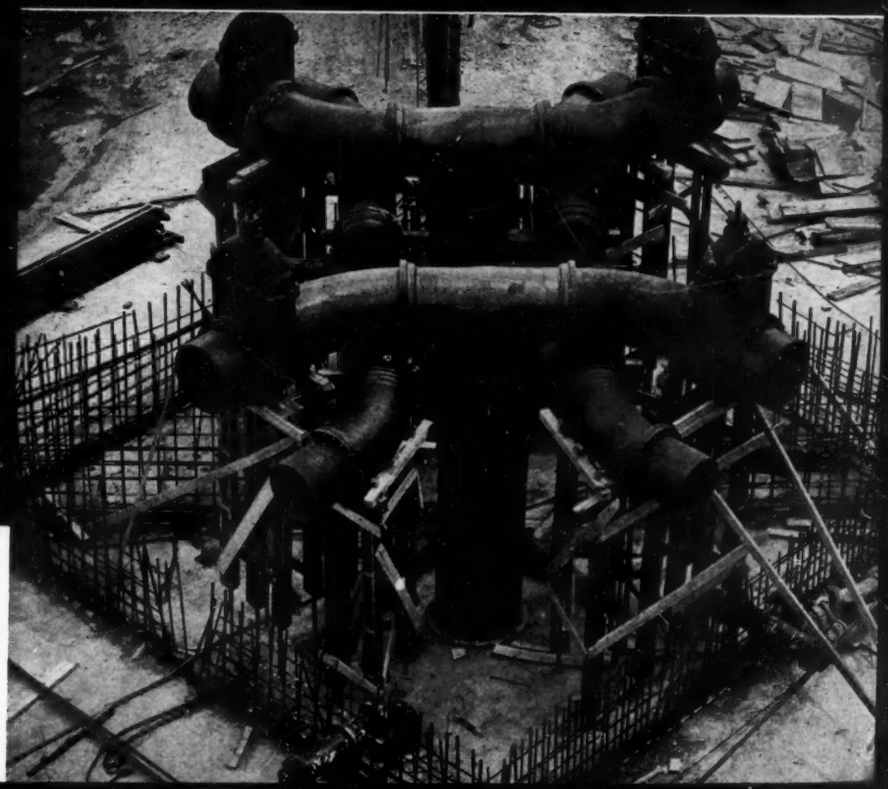

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Fig. 11—Detritors at Baltimore, Md.
The 3 Units Have a Design Capacity of 100 M.G.D. Each; at a Power Consumption of 4½ H.P. Each.

have extended over a period of some years. Preliminary field work was conducted at Philadelphia at the Frankford Grit Chambers in 1926 and 1927. In 1928 a more extensive program was carried out at Harrison, N. Y., simultaneously with our Westport flume tests. A vast amount of theory and practice had to be correlated and reconciled before there could be evolved an entirely new unit, based upon a new concept of optimum design factors, such as is the Detritor. Today there are 110 of these machines in operation here and abroad. Operating data from 41 different installations are given in the accompanying table.

Conclusions

Based on experience, and studies cited in this paper, we believe that a satisfactory grit chamber should be designed on the following basis:

One—Capacity should be in direct proportion to the area, regardless of the relations of width, depth, length, and velocity.

Two—Grit particles should be pictured as settling at the same velocity, with respect to the moving stream of sewage, as in a quiescent pool.

Three—The chamber should be designed in accordance with the specific characteristics of the grit to be removed, the aim being to remove all grit particles coarser than 65 mesh. And, in certain cases, all settleable non-organic particles coarser than 100 mesh.

Four—The final washed grit should be generally free of putrescible matters and in no event should it contain in excess of 3 per cent by weight of such.

Five—Grit should be drained completely of visible free-water before its discharge from the washing and draining units.

Six—The chamber should be so designed hydraulically as to operate readily over the full range between maximum and minimum flows, without appreciable loss of head.

Seven—The collecting and washing mechanisms should at all times deliver a clean grit within the limits specified in *Three* and *Four* above, without any adjustments being required for variations in rates of sewage flow or grit deposition.

Eight—The entire unit should be so designed structurally and mechanically as to preclude any possibility of septic action, odors, or unsightliness.

All of these desirable features may be readily obtained if the specifications on which bidding is solicited are drawn on a uniform basis that require all purveyors of competitive types of equipment to give the same guarantee in respect to performance and delivery of grit that measures up to a uniform established standard in respect to content of water and putrescibles.

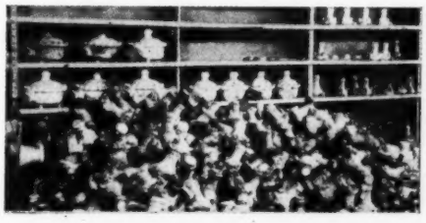
"DO NOT BUILD A FIRE IN YOUR METER BOX!"

This was the plea sent out to consumers by the Water Department of Little Rock, Arkansas.

However, it was all too late to help much in 1940, as evidenced by the accompanying picture of a part of $5,000 worth of meters damaged in Little Rock by customers who tried their own thawing procedures by building fires in meter boxes.

Little Rock, like many another city of the mild Southland, experienced some real "Cold Weather Troubles" in 1940 and didn't have to wonder longer what they were really like when reading about these worries of their Yankee brothers.

From many places in the South came S.O.S. calls for thawing apparatus and suggestions of procedure. From L. A. Jackson, General Manager of Little Rock's Water Works has come information that there they had eight thawing units at work night and day to handle over 5,000 thawing jobs. In this Little Rock suffered an unparalleled contingency expense to the Water Department entered as—"Thawing Services and Repairs, 1940"—$10,000. Such an entry will stand out as historic red-ink on Little Rock's ledgers—or, at least Mr. Jackson hopes as much.



$5,000 Worth of "Souvenirs"

Even so, evidence shows that 800 consumers in attempting to help themselves, built fires in meter boxes —and added further costs by putting about $5,000 worth of meters out of commission.

In an open letter to consumers, a picture captioned $5,000 Worth of Souvenirs" was sent with the explanation of the delicacy of the water meter mechanism and a plea —"PLEASE DO NOT BUILD A FIRE IN YOUR METER BOX."

GRIT CHAMBERS*

Schemes of Yesterday -vs.- Modern Mechanized Design

By M. B. TARK and J. J. GILBERT
Engineers
LINK-BELT COMPANY
PHILADELPHIA, PENNA.

EVER since the first sewage treatment plants were put in operation, grit in sewage has proved troublesome and has had to be settled out in separate chambers, ahead of other settling units. Chambers of many shapes, providing velocities from 2 inches to 2 feet per second, were built and more or less served their purpose.

Grit chambers were usually built in multiples. One or more was closed down and drained, after which the accumulated grit was manually removed. Such cleaning of these chambers was a disagreeable task and very early in the art, elevators or grab buckets were installed for the removal of the grit. The elevators were either stationary or mounted on a truck traveling the whole length of the grit chamber. The installation at Birmingham, England is a good example of such a traveling machine. The grit was discharged directly into cars along side of the chambers. Grab buckets were used in Hamburg and in several American installations.

Design and Operating Practices

The ideal grit chamber should remove all sizes of grit that may cause trouble in the other units of the plant. The putrescible matter in the grit should be very low. Due to the characteristics of grit, the latter attainment is difficult in many plants, as the separation of the grit from the organic material depends upon specific gravity and the shape of the particles. Very often the grit particles are covered with grease or adhere to organic material. Grit has been very aptly described as "sand on roller bearings."

Many methods have been tried to separate the organic material from grit. One of the most common is the maintenance of uniform optimum velocities through the grit chamber. Such selective velocities are supposed to permit the grit to settle, while the lighter organic materials pass through the chamber to be treated in the other units of the plant. A velocity of 1 ft./sec. was almost universally employed to accomplish this result and a number of grit chambers were designed to provide this velocity. To maintain a uniform velocity at all times, chambers with "V" shaped cross section were designed to take care of variations in flow. In other cases rectangular chambers were installed with gates or weirs at the effluent end to maintain this velocity. Very shortly it was found that the large volume of organic material deposited in the grit made it a very objectionable material to handle. In conse-

* This paper was one of a group of three on the same topic presented November 29, 1939, before the Sanitation Group of the Am. Soc. of Mechanical Engineers in New York City.

Month 1937	Flow M.G.D.	Velocity Feet per Sec.	Grit Removed: Total Cu. Ft.	Cu. Ft. per M.G. Sewage	Per Cent Moisture: Fresh	Per Cent Moisture: Washed	Per Cent Putrescible Matter: Fresh	Per Cent Putrescible Matter: Washed	Per Cent Putrescible Matter: % Red.	Organic Nit. Mg. per Gram Dry Solids: Fresh	Organic Nit. Mg. per Gram Dry Solids: Washed	Organic Nit. Mg. per Gram Dry Solids: % Red.
January	60.0	1.31	2565	0.30	40.7	34.6	3.35	2.36	29.4	1.67	1.00	40.5
February	59.7	1.31	2025	0.29	32.6	21.9	2.05	1.33	35.1	1.07	0.76	26.5
March	59.1	1.29	675	0.09	31.6	29.4	2.36	1.87	19.1	1.23	0.94	27.1
April	59.3	1.30	4590	0.57	45.2	36.2	3.57	1.70	42.7	1.57	0.86	41.0
May	59.1	1.26	6885	0.83	49.8	24.2	5.45	1.96	63.8	2.51	0.77	41.8
June	59.2	1.27	7290	0.91	37.2	22.2	1.81	1.03	42.2	1.23	0.60	51.6
July	60.0	1.29	8640	0.96	32.9	22.9	2.58	1.87	21.2	1.45	0.83	32.8
August	60.8	1.32	8370	0.85	42.9	33.5	2.96	2.02	32.8	1.49	0.84	42.0
September	60.9	1.33	3591	0.41	44.9	27.7	2.65	1.30	46.9	1.26	0.73	40.8
October	60.7	1.32	4617	0.49	40.6	30.4	3.80	1.41	59.0	1.61	0.50	66.8
November	49.7	1.09	3591	0.46	46.2	41.5	5.17	4.50	14.1	2.71	1.88	31.9
December	47.2	1.03	3105	0.39	50.5	31.9	4.06	1.92	68.3	2.91	0.96	60.5
Total Average	58.0	1.26	55,944	0.56	41.7	28.9	3.33	1.85	44.4	1.72	0.85	50.5
1936 Total Average	41.2	1.20	67,594	0.93	37.4	30.9	2.30	1.45	37.0	1.44	0.79	45.2

LINK-BELT COMPANY

Grit Removal and Washing Results at Chicago's West-Side Plant

quence, other means providing a better separation have been devised and employed. Amongst these were the following schemes.

Roughing tanks, with about 10 minutes' detention, were installed ahead of settling tanks and a constant volume of the settled material was pumped continuously through the much smaller grit chambers, providing a uniform velocity. Several plants of this type were built, the principal ones are at Akron and Dayton, Ohio and the West Side Plant of Chicago. These plants did not work out as expected, because as much as 60% of organic matter was contained in the discharge from the grit chambers handling the detritus tank deposits.

Another method was that of washing the grit after its removal from the grit chamber, and this is now accepted as the most practical and effective process. One of the first plants designed to use this method was at Philadelphia. The original design provided a machine, somewhat similar to a dredge mounted on trucks, which was to remove and discharge the settled material to a trough. The trough was to discharge the grit into a tank, in which it was to be thoroughly washed and the organic material floated off by wash water applied at the bottom. The price on the machine for the removal of the grit exceeded the money available and it was never installed. The grit is now removed by shoveling from the chamber to a water ejector which discharges to the wash tank. A very clean grit is obtained by this method so that the wash tank is used only for storage. A similar method on a smaller scale is used at the Boonton, N. J. plant and probably at a good many others.

Grit Washing Developed

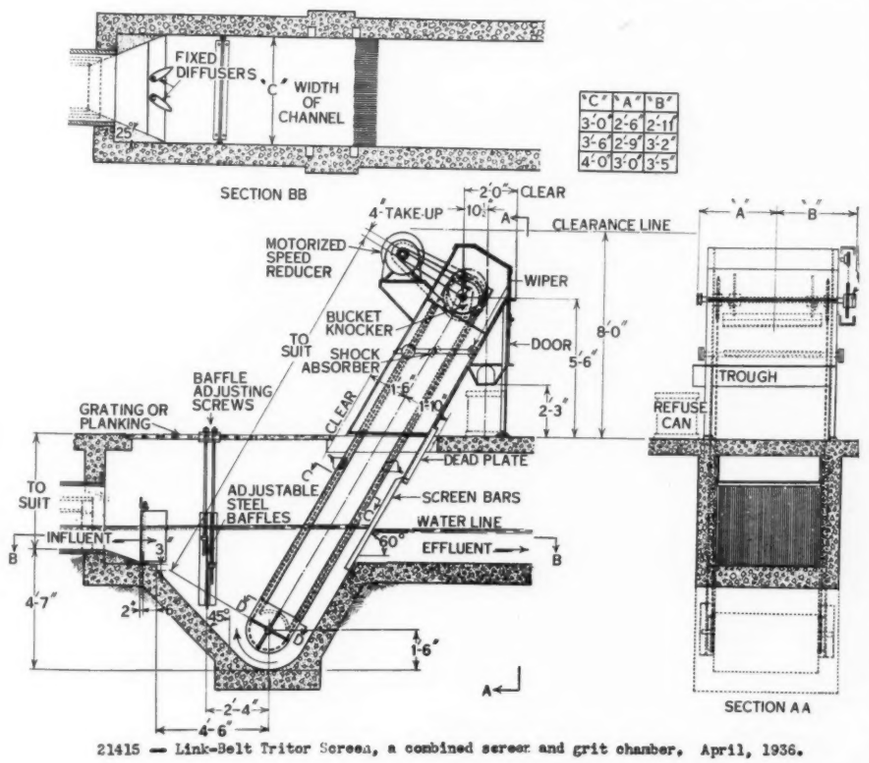
About 12 years ago a demand arose for the removal and washing of grit by mechanical means. To meet this demand at least two manufacturers designed machines for such purpose, the earliest installations being that at Chester, Penna. and another at Harrison, N. Y. which followed shortly.

The mechanism in grit chambers has two objects. First, to operate at such a speed to permit the settling out of the grit but to keep most of the organic material in suspension so that it will be swept out of the grit chamber, while the higher gravity remains behind. Second, to gather together and discharge the collected grit above the water line of the chamber.

If the collecting mechanism does not effectively stir the grit deposited in the chamber, but merely serves to collect all of the grit and organic material that settles in the chamber and deliver it to the washer, the load on the latter unit will be unduly heavy. As a result the performance of the washer is apt to be unsatisfactory unless this unit is designed for such extra duty and a comparatively large volume of wash water is used. At the West Side Plant of the Sanitary District of Chicago, flight conveyors were installed to remove the grit from two of the chambers, this grit was carried to a screw washer, followed by a dewatering screw, and thereupon discharged to railroad cars. A clean grit was obtained by this rather complicated method. The installation was experimental and was mostly made up from material at hand. The washer was recently removed.

AMOUNT OF SEWAGE TREATED DAILY				REMOVAL OF GRIT	
INDICATED BY VENTURI METERS			TEMP. SEWAGE °FAHR.	GRIT	
MONTH	RAINFALL TOTAL	M.G.D.		CU.FT.	PER M.G.
JANUARY	3.16	28.51	52.6	259	9.10
FEBRUARY	1.93	28.94	51.0	227	7.85
MARCH	2.13	27.34	53.0	225	8.24
APRIL	2.52	27.58	56.0	228	8.28
MAY	2.99	22.01	60.0	139	6.32
JUNE	4.95	26.94	64.0	161	5.98
JULY	6.95	31.50	66.0	160	5.08
AUGUST	2.18	24.69	68.0	100	4.05
SEPTEMBER	7.81	26.59	68.0	161	6.05
OCTOBER	1.44	21.06	65.0	117	5.55
NOVEMBER	1.71	20.59	62.0	150	7.28
DECEMBER	2.42	29.55	56.0	134	4.54
YEARLY AVERAGE	TOTAL 40.19	26.28	60.1	172	6.54

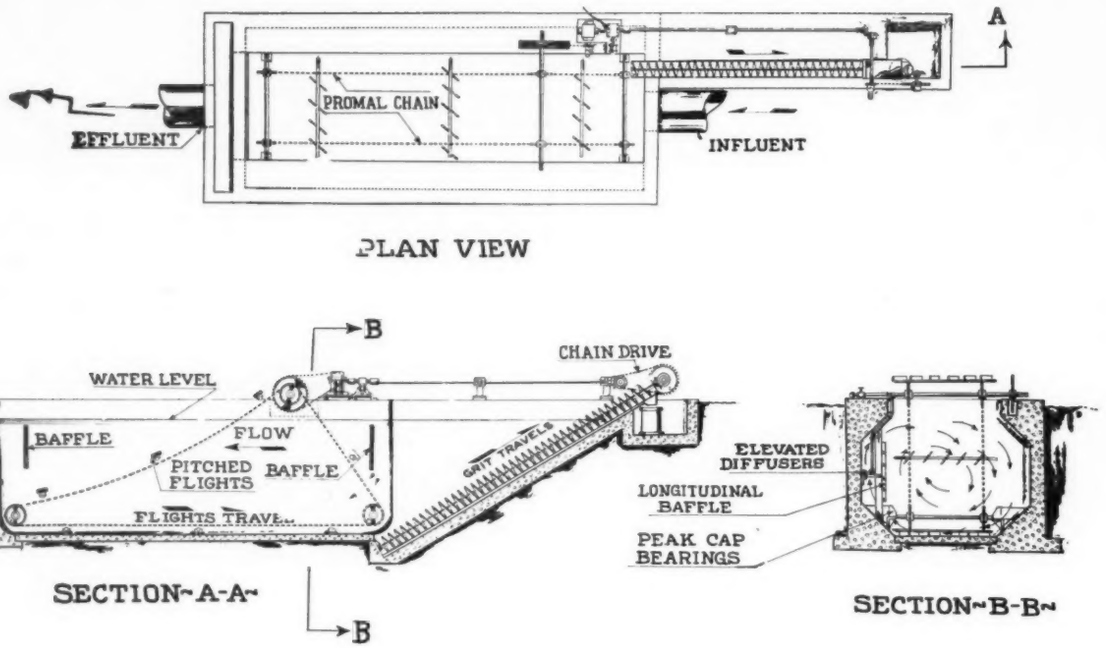
Operating Data—Elizabeth, N. J.
Note the effect of increased velocity (May forward) in decreasing volume of organics removed as "grit."



21415 — Link-Belt Tritor Screen, a combined screen and grit chamber, April, 1936.

The Link-Belt "Tritor Screen"
A Combination Unit—Screen and Grit Chamber.

Each drag conveyor of the Chicago unit consists of a single strand of combination chain with 2 x 6 wood flights spaced approximately every 2 ft. 6 in. Each flight is equipped with renewable wearing shoes. The original installation had the flights spaced every 5 feet, but considerable breakage of flights occurred during the time of storms. Due to the heavy load of grit, for the past year and one-half the conveyors have been operating with the flights spaced every 2 ft. 6 in. approximately. The speed of the conveyor is approximately 2.4 ft. per minute and the inclined portion of the conveyor is 30° to the horizontal. When the washer was in service, the grit was discharged on a belt conveyor running at right angle to the two grit chamber drag scrapers. From the washer it was discharged onto a distributing belt conveyor traveling above flat cars. Now that the washer has been removed, the grit travels direct from the drag conveyors in the grit chambers to the cars without any washing.



Spiral-Flow Grit Chamber Employing Compressed Air
Equipped with "Straightline" Collector and Elevating Screw Which Cleanses and Dewaters Grit.

When washing grit, raw sewage was used to do the washing and a pump having a capacity of 90 gallons per minute was operated continually, pumping the influent from the grit chamber direct to the washer. The grit was dumped directly into the washer and when they started up, very poor results were obtained. To get better results, both the grit and the wash water were added into a spiral trough above the water level in the screw washer and allowed to flow spirally down into the screw compartment. This turbulent action improved the washing of the grit considerably and the accompanying results reveal that a fairly clean grit was obtained.

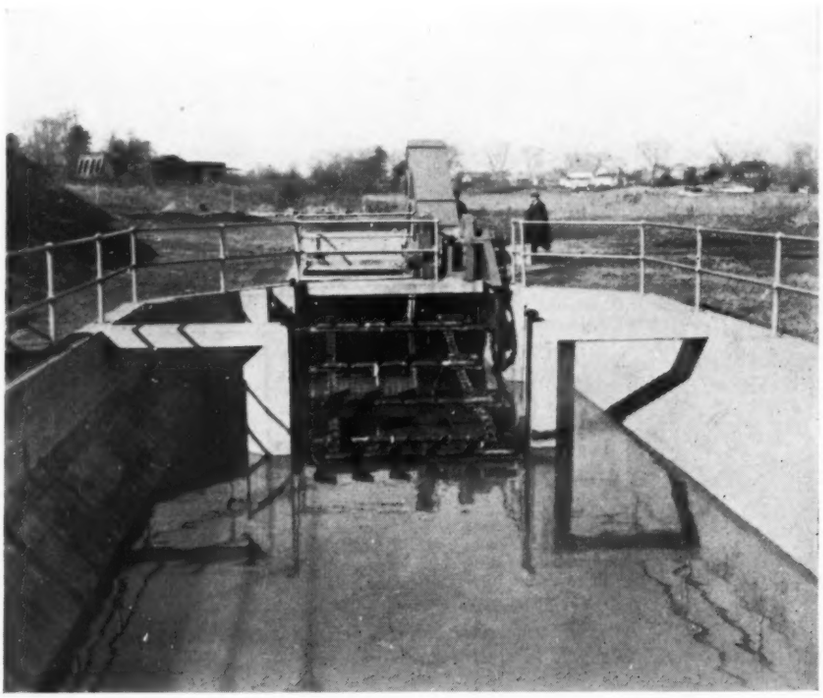
It was also found that 90 gallons per minute of wash water was not sufficient at the time of storms and a new pump, having a capacity of 200 gallons a minute, had to be installed. This pump runs continuously regardless of the amount of grit going to the grit washer. During storms the volume of grit is about twenty times the average.

An Ingenious Grit Chamber

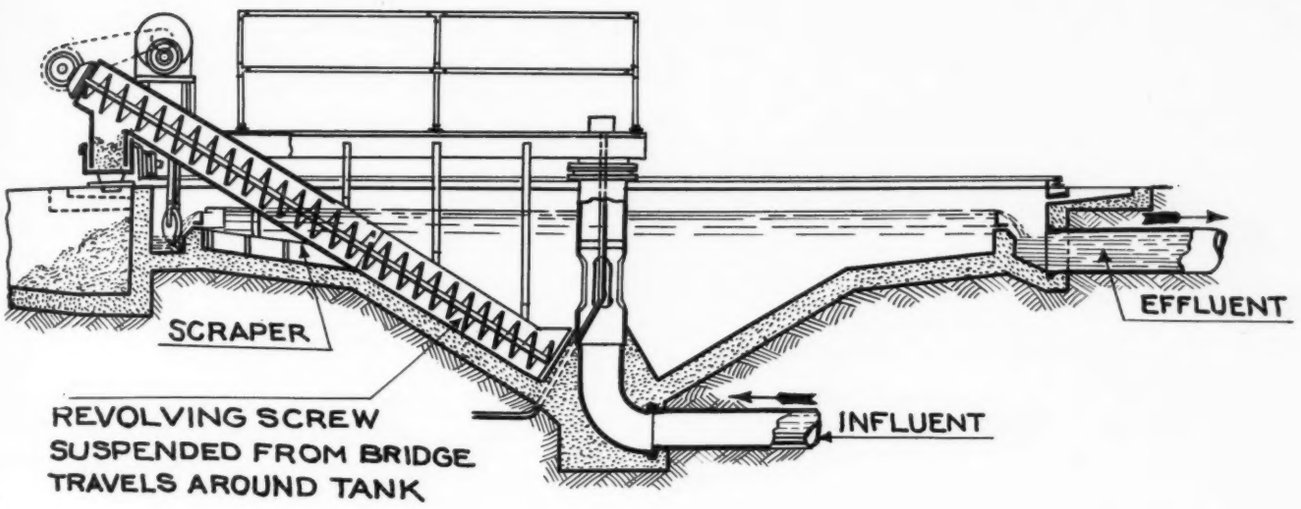
A rather ingenious grit chamber was designed by Blunk, Chief Engineer of the Emscher Genossenchaft. It consists of a number of concentric compartments with over flow weirs which are set at different levels so that more and more of these compartments come into use as the flow increases. The grit and some organic matter settle in the hopper bottom and the grit is thoroughly washed by means of water and air jets before it is discharged by means of an air lift. A good grit is obtained by this method even though the sewage is heavily charged with fine organic solids.

The "Tritor Screen"

The "Tritor Screen" is a machine manufactured by the Link-Belt Co. It combines the functions of a mechanically cleaned bar-screen and grit chamber. (See illustration.) This screen is especially recommended for small plants where it is not economically feasible to install too many separate mechanical units. Adjustable baffles at the influent maintain a velocity of approximately one foot per second at the bottom of the sump. The heavier grit settles to the bot-



The Grit Chamber of the Rahway Valley (N. J.) Plant
"Straightline" Collector and Dewatering Screw Conveyor



CIRCULINE GRITCHAMBER

The New "Circuline" Grit-Chamber

Operates on the Radial Flow Principle. Features Rugged Design and Revolving Screw Mechanism.

tom, while the organic matter is kept in suspension. The floating material is collected on the bar rack, while the grit is removed by means of buckets. Automatic intermittent operation is provided by means of a time clock. There are over 60 of these machines now in use.

The "Straightline" Grit Remover

The Link-Belt "Straightline" Grit Chamber consists of a collector with pitched flights that turn the settled material over and over while moving it to one side or the center of the chamber. Here the grit is picked up by the screw of the washing mechanism, which elevates the grit while it is being washed. The duty on the collectors and wear is very much greater than that of similar collectors in settling tanks. Such necessitates use of a different type of chain with larger wearing surfaces, and the tracks and other sliding surfaces are provided with abrasion resisting steel.

The velocity of flow through such chambers must be maintained at 0.5 ft./sec. in order that the organic material liberated by the screw washer, and kept in suspension by the action of the flights, may be continuously washed out. Results obtained by maintaining the effective 0.5 ft./sec. velocity at the Joint Meeting Plant located in Elizabeth, N. J., are revealed in the accompanying table. During the first four months, two grit chambers were kept in service, whereas in the following months only one chamber was employed. The decrease in the recorded volume of grit removed was entirely due to the more efficient flushing out of heavy organic materials when operating the chambers at the higher velocities.

The great variation in the removal of grit from day to day at many plants is well illustrated by the records at the Peoria, Ill. plant, where the volume of grit removed varies from 2 cubic feet to 560 cubic feet in one day, following a 7 inch rainfall. At Peoria, although the average chamber velocity was only 0.3 ft./sec.; the cleansed grit contained but 9.8 to 17.9% velocities and only 0.35 to 0.53% putrescibles.

Where it is necessary to use a separate grit washer, a certain minimum volume of wash water is required. This wash water may be either clarified sewage or mixtures of clarified sewage and clean water. In such washers the arrangement of the influent and effluent channels is of the greatest importance and much of the success of the operation depends upon the arrangement of the water jets employed to separate the organic material from the grit and float it to the effluent channels.

Spiral Flow Type of Chamber

The Link-Belt Flow Grit Chamber makes use of the same mechanical equipment as the "Straightline" chamber. The chamber, however, is constructed so as to permit introduction of compressed air in a manner to create a spiral flow in the chamber, (see illustration). The purpose of the air is that of creating a uniform velocity regardless of fluctuation in sewage flows. The end sought is that of insuring that organic matters are maintained in suspension for effective sweeping out by even the minor sewage flows. Thus, a much cleaner grit and less volume load is imposed on flights and the washing mechanism. The scheme is very effective.

The New "Circuline" Grit Chamber

The Link-Belt "Circuline" Grit Chamber (here illustrated) is a new development and has many desirable features not found in any other type of grit separatory unit. The sewage and grit enters at the center at a very high velocity, which tends to sweep the organic materials toward the circumferential weir. A rotating screw maintains uniform agitation in all parts of the tank, separates the grit from the organic material and throws the organic material upward and toward the outlet. A travelling scraper removes any materials that may strand in the effluent weir.

Such a machine will be able to handle very heavy deposits of grit on account of its ruggedness. Another decided advantage is its simplicity, flexibility, and low head loss in handling the large flows.

GRIT—ITS COLLECTION AND WASHING*

With Particular Reference to Jigging as an Advanced Method, and a New Type of Washing Unit

By R. D. NICHOLS**
Engineer
THE JEFFREY MANUFACTURING CO.
COLUMBUS, OHIO

THE removal of grit from sewage, prior to sedimentation of the organic solids in clarifying units, has been practiced for many years. The efficient and economical practice of this important phase of sewage treatment requires several steps which, if properly followed, will produce the results desired. These steps are:

(1) First, the larger suspended solids should be removed from the crude sewage by effective screening.

(2) Thereafter, the sewage is passed through a channel or chamber, designed to give only a brief period of detention and to provide velocity of flow which will permit the gritty materials to subside while all but a fraction of the organic materials are swept through.

(3) The settled material must be removed from the chamber, preferably at frequent intervals by continuous type mechanical scrapers or collectors.

(4) Then, unless an efficient means of separating the residual organic matters from the collected grit, and return of such to the sewage, is not employed, disposal of the grit mass constitutes an added problem and an extra expense.

During the past few years new plant designs have incorporated mechanical units for screening out coarse solids, for removing deposited grit from the settling chamber, for the washing of such deposits to free the grit of organic solids, and return of the dirty wash-water to the sewage for subsequent treatment.

This paper will now briefly enumerate some of the elementary rules of design which have been in vogue in recent years. This, in order that these rules may be compared with observations of the writer and others with whom the problems have been discussed.

Detention Periods

In designing grit chambers, engineers have generally considered one-half minute as the minimum detention period permissible, based on maximum flow. Approximately one and one-half minutes' detention has been the maximum, except under most unusual conditions.

Only recently have control devices been widely used to maintain a fairly constant velocity throughout variations of flow.

The prevailing factor in determining detention period is the maximum sewage level and the closeness of adherence to the rule of thumb law of 10 feet of length for each foot of depth. Generally in the design of long narrow channels, for a maximum sewage depth of from 3 to 4 feet, the rule is followed closely. In some larger plants there has been some deviation in this rule, reducing length and detention period.

Velocity of Flow

A velocity of flow through grit chambers or channels of one foot per second has been considered adequately low for the settling of inorganic solids. This does not mean, however, that some organic solids will not settle also. Velocities lower than one foot per second usually results in an excessive amount of organic solids appearing in the settled grit.

Prior to the use of facilities for automatically controlling flow velocity, operators attempted to obtain clean grit by controlling the depth of sewage flow in the channels, thereby maintaining velocity within a relatively narrow range.

The related rules are based upon the free settling velocities of solids and the assumption that fine grit is in suspension in the upper strata of flow as the sewage enters the separatory unit.

The writer questions whether inorganic solids of any consequence are actually found in suspension in relatively low velocity of sewer flow (under 3 ft. per second), unless there is some artificial means to create turbulence. Grit in sewers, influent channels or screen chambers, designed so as to preclude sudden changes in velocity, has already had an opportunity to settle. It may be termed a "lazy animal" and will be found on or near the bottom where it may be collected. Therefore, in designing grit channels, the velocity should be reduced in a manner that will provide little chance of creating disturbance or turbulence. Organic solids that settle out with grit in chambers of very low velocity are quite difficult to separate unless some method of classifying is employed in the washing operation.

Relationship of Length and Depth

The writer has not reviewed all the literature on the subject, but Bloodgood (Sewage Works Journal, May 1939) refers to a reduction in the length of grit channels without seriously affecting the results. The channels at Indianapolis were 55 feet long and had a constant velocity weir at the effluent end, designed to maintain a velocity of one foot per second. The detention period, of course, was approximately one minute.

The water depth at maximum flow was approximately 10 feet; therefore the ratio of length to depth about 5.5 to 1. These channels were reduced from 55 feet to 20 feet in length by moving the foot shaft of the collector mechanism and the constant velocity weir. With the new arrangement the detention period is only 20 seconds, and the relation of length to depth is now 2 to 1. In the Indianapolis plant the main sewer, and influent channels are in substan-

* This paper was one of a group of three, presented before the Sanitation Group of the Am. Soc. of Mechanical Engrs. in New York City, on the same topic. All three are presented in this issue by permission of the Society.—Ed.

** Manager, Sanitary Engineering Division.

tially a straight line of flow, the grit has already settled out and, in consequence "drifts" into the grit chamber.

Bromage (Sewage Works Journal, May 1939) concurs in this opinion. He states: "Immediately beyond the screens are two curved weirs and a horizontal slab which diverts the lower strata of sewage, which contains the road grit, into two detritus separating wells, while permitting the upper strata to pass straight on."

Reference to the Bromage article does not mean that the writer believes grit channel designs should provide for a by-pass for the upper portion of sewer flow. However, it does substantiate the opinion that grit is carried in the lower strata of a free straight-line flowing sewage stream and, in consequence, can be removed in short channels as satisfactorily as in long ones, especially if velocity control devices are employed.

The control of velocity, the absence of undue turbulence, and the utilization of collectors that create relatively quiet pools between the conveying elements should be found to permit the use of shorter channels and reduce capital expenditures as well as cost of maintenance.

Grit Removal Mechanisms

Grit removal mechanisms are of two distinct types—those that merely remove grit and those that combine washing with removal.

There are scraper conveyor mechanisms that move grit along the bottom and deliver it to an inclined screw for washing . The removal mechanisms have conveyor elements interspersed with plows that move solids back and forth, thus assisting the washing operation.

There are scraper conveyors that traverse the bottom of channels and continue upon an inclined deck to wash the grit at the point of emergence from the liquid and further to dewater it. Some of these also have plows for abraiding the settled grit by moving it back and forth.

There are square tanks that have rotating collector mechanisms that deliver the collected grit to a washing compartment, usually positioned alongside the tank. An oscillating rake type mechanism washes and elevates the grit, dewatering it after leaving the sewage.

There are V-bucket conveyors longitudinally traversing the channels, to collect the grit and elevate it. Some of these have plows interspersed between the buckets to effect a washing. There are V-bucket conveyors also used in combination with scraper type conveyors.

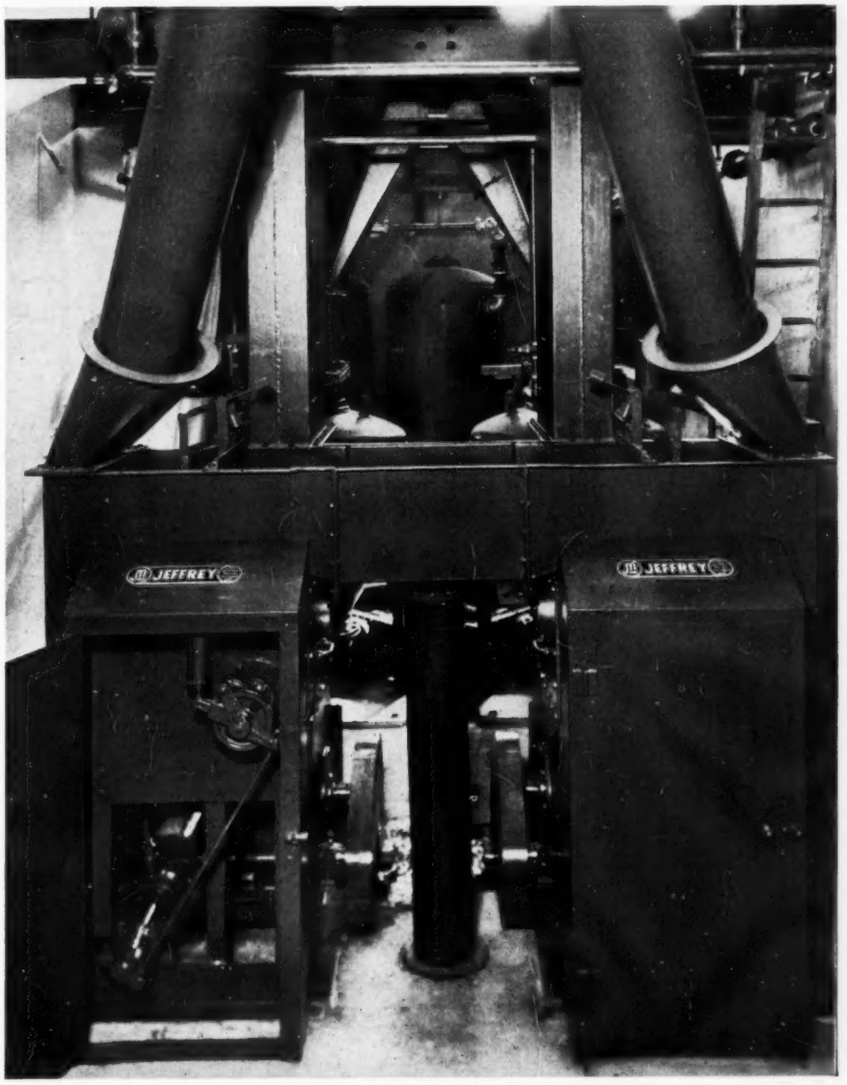
Some designs have separate grit washers located outside the flow of sewage. Screw conveyors have been used in separate compartments. The oscillating rake mechanism has also been used in separate compartments.

The Newest Grit Washing Unit

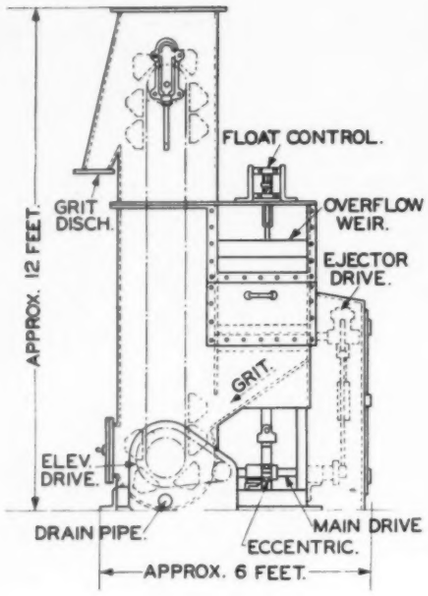
The most recent development in method of grit washing and apparatus is a combination of the V-bucket collector and elevator which delivers the grit to a machine called the "JIGRIT."

The "Jigrit" method not only "scrubs" the solids to free the adhering organic matter but classifies these solids and finally separates them, sending the organics over the weir in the wash water which is returned to the sewage stream. The washed grit is dewatered and delivered to containers or vehicles for final disposal. (See cut.)

In the new "Jigrit" the solids are formed into a bed on a screen plate below which is a box for admission of wash water. Water moves up through the screen plate to open the bed and permit stratification of the solids in accordance with specific gravity. Interruption of the upward flow closes the bed. This alternate opening and closing of the bed not only classifies the particles but the jigging "scrubs" them, freeing adhering organic solids which move to the top strata and pass over the weir with the wash water along with the coarser organic solids. The cleanest grit settles to the bottom of the bed, the screen plate retaining the coarse particles, while the performations through the screen plate permits the small particles to pass into the box



New Jig Type Grit Washers—The "Jigrit"
These Classifying Grit Scrubbers Provide Automatic Wash Control and Turn Out Grit Containing Less than 0.5% Putrescibles.



The "Jigrit"
Showing General Dimensions and Design.

for subsequent discharge as washed grit.

At present the "Jigrit" is made in two sizes: No. 4, having 4 square feet of screen area and a capacity of from 4 to 5 tons per hour of feed. No. 1 "Jigrit" having only one square foot of screen area and a capacity of approximately one ton per hour of feed.

The larger unit (see cut) is provided with a diaphragm positioned below the screen plate and adapted to be moved in a predetermined cycle by a power operated eccentric mechanism. Such movement creates an upward and downward current of water which imparts a breathing motion on the bed. Automatic controls govern the rate of discharge of coarse clean grit from the lower strata of the bed, while maintaining a bed depth within close limits. This bed of grit acts as a filter and prevents the passage of organics with the clean bottom grit. A float positioned in the bed rides the top of the coarse grit strata and moves with each pulsation. As the coarse grit strata increases in depth, the float rises and operates devices to cause rotation of a star type draw. As the coarse grit strata is lowered, owing to withdrawal, the float moves downward and operates the mechanism to stop the ejector, or draw. All washed grit is removed continuously from the box by the perforated bucket dewatering elevator.

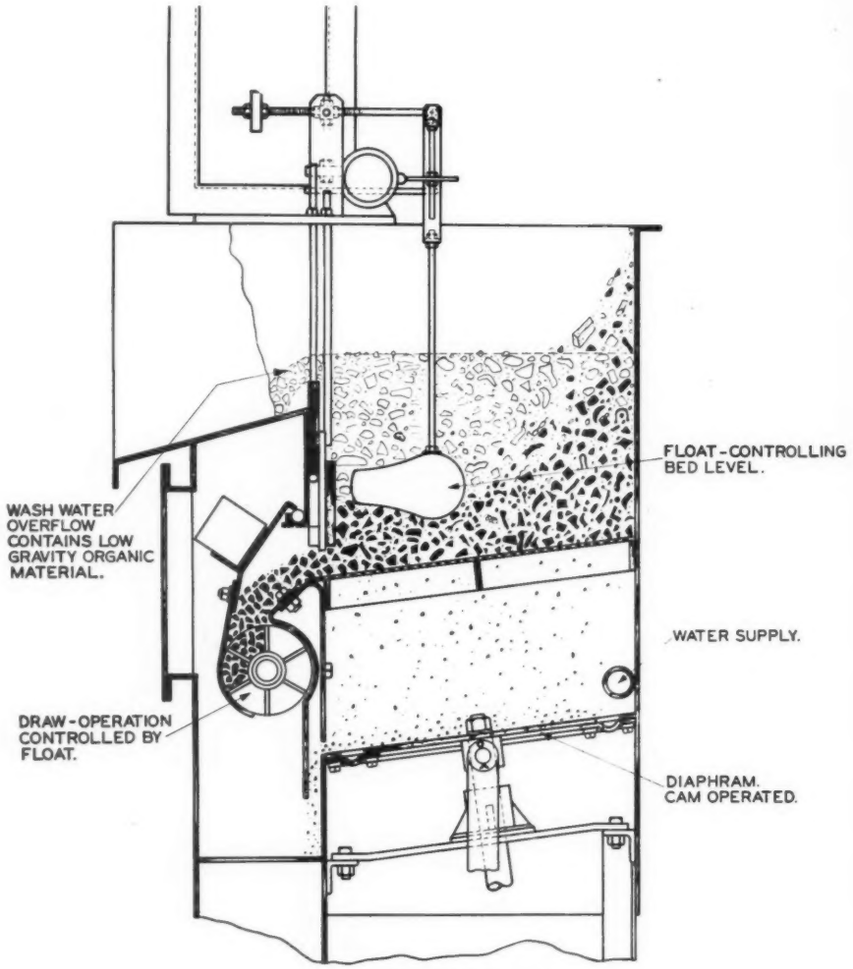
The Unit for Small Plants

The smaller unit ("Jigrit" No. 1) operates on the same general principal as the heavy duty unit, but does not have automatic controls for the discharge of material from the strata of coarse grit. In this unit the bed of grit is formed in a basket hung from from the drive shaft by eccentrics. In operation, the basket moves in a fixed cycle. (See cut.) As the basket moves down, water is forced through the bed to open it, this operation allowing the fine grit to pass the perforations of the screen plate while the coarse washed grit is retained by it. This unit, however, has a float and an indicator by which the operator can determine when coarse grit should be withdrawn. The grit draw at the end of the screen plate is movable from a closed position to an open position by manual operation. In "Jigrit" No. 1 all washed grit passes to the hopper below the basket and is continuously removed by a screw conveyor.

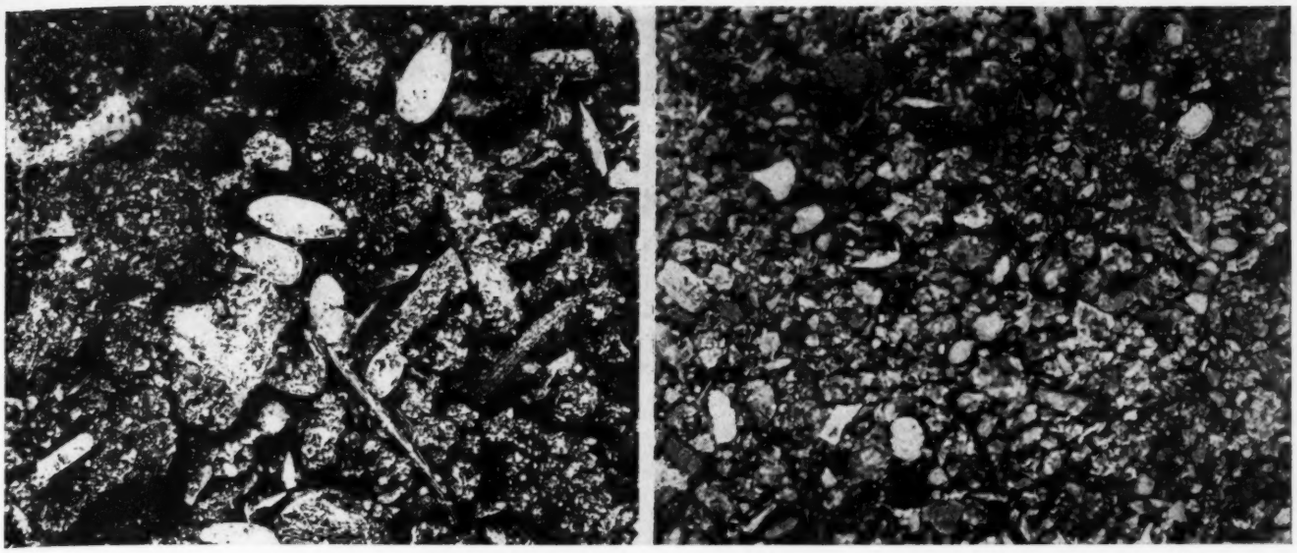
What Constitutes Clean Grit?

Results of grit washing methods are usually expressed in the reduction of putrescible solids, the latter being determined with "Dazey Churn Test," as given in the July 1930 issue of Sewage Works Journal. Such determinations alone do not, however, convey the true efficiency of the method for the reason that large organic solids, such as, seeds, macaroni, spaghetti, worms, etc., are not adequately disintegrated in the test and are retained in the Dazey Churn as residue, thus being recorded as inorganics rather than organics.

By using the Jigrit method and equipment, reductions in putrescible solids as high as 90% can be obtained with little or no loss of inorganic solids with the overflow. It is believed that unwashed grit removed from well designed, mechanized grit chambers contains an average putrescible solids content of approximately 5 percent. If this be reduced 90%, only 0.5% putrescible solids remain in the washed grit. In addition, the removal of the difficult coarse or large organic solids makes the grit


FLOAT-CONTROLLING BED LEVEL.
WASH WATER OVERFLOW CONTAINS LOW GRAVITY ORGANIC MATERIAL.
WATER SUPPLY.
DRAW-OPERATION CONTROLLED BY FLOAT.
DIAPHRAM. CAM OPERATED.

The Heart of the "Jigrit"
The pulsating diaphragm causes the grit bed to breathe and classify the particles. Coarse grit remains above the perforated false bottom, while wash water passes up to sweep out the mascerated organics, and fine grit drops through the perforations. The depth of the coarse grit bed is automatically maintained by the float mechanism which controls the star type draw gate.



The Crude and "Jigritted" Product

In which 4.5% putrescibles (including seeds and the like) have been reduced to 0.4% to yield a nuisanceless product of pleasing appearance.

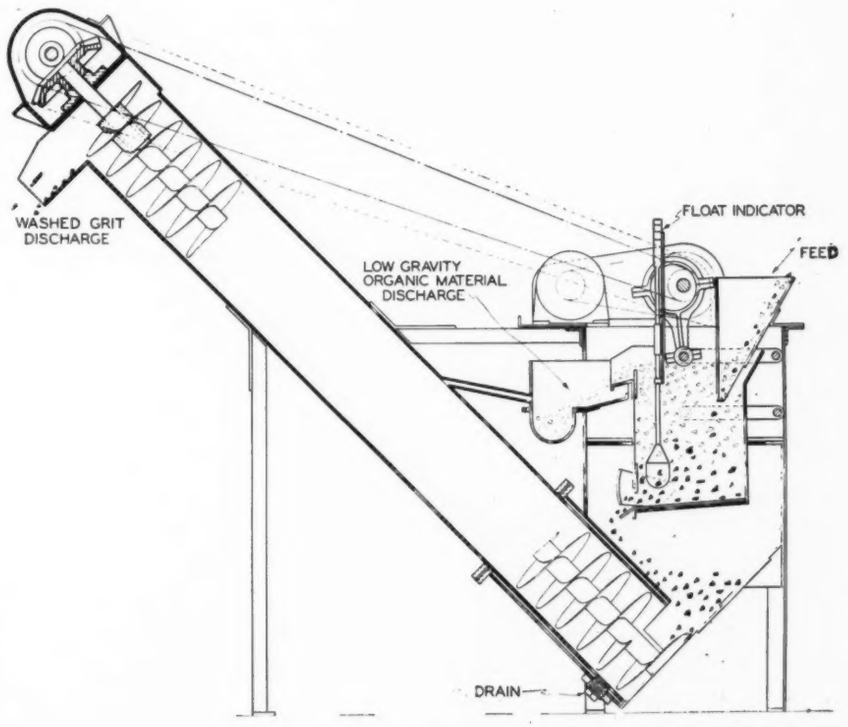
much more pleasing in appearance (see cut) and, thereby, more suitable for use as fill or walkways about the plant; also, reducing to a minimum the cost of disposal.

Results obtained in a series of tests using Jigrit No. 4 equipped with automatic controls, are as follows: The average putrescible solids content in the feed was 4.77%, while the average washed grit contained only 0.65% putrescibles. The photographs of the samples picture the degree of cleanliness and pleasing appearance of the jigged grit. The differences in the Dazey Churn residue of feed samples and the washed grit may be found also in ash determinations. In this series of tests the average residue ash was 69.6%, while the washed grit ash averaged 75.6%, an increase of 6%, due to the reduction of organic solids in the washed grit.

A thorough test of the small, manually controlled "Jigrit" No. 1 was conducted recently. These tests proved that this unit can be manually controlled to produce results equal to those from the automatic unit. For the series of tests the average feed contained 4.5% putrescible solids and the washed grit averaged of only 0.4% putrescibles, a reduction of 91%.

"Jigrit" No. 4 requires about 20 square feet of floor area and a minimum of approximately 14 feet of height. It requires only 2 h.p. for operation and is a self-contained unit. Approximately 40 gal. of wash water per minute are required. Where preferred clarified sewage or plant effluent may be used as wash water.

Jigrit No. 1 requires about 16 square feet of floor area and less and less than 7 feet of head room. It is a complete factory assembly, requires only ½ h.p. for operation and only 10 gallons of washing liquid per minute.



The Non-Automatic "Jigrit" for Smaller Plants

Is in all respects similar to the larger unit, except that the depth of coarse grit is indicated, only, and must be manually regulated by intermittent withdrawals.

The Editor's Comments

A PORTENTOUS DROUGHT

THE "big-boss," Halbert P. Gillette—to us "H. P.," and to others who worked with this red-haired dynamo in earlier days it was "Horse Power" Gillette—some years ago became interested in "doing something about the weather," besides grumbling about it. His chief interest developed in the direction of the possibilities of predicting, some time in advance, the weather trend—i.e., on-coming wet and dry years and the approximate period of duration, intensity, and seriousness of recurring dry periods and flood years.

His trend of thinking led him to search for a possible index of long range trends. Records kept in the time of man having proved wholly inadequate, as has so well been proved in recent years, be turned to those long recorded happenings of Nature which are revealed to some extent by the growth rings of the oldest living things on this earth, the big-trees; but, of far longer time and geographically more inclusive, the oldest things on this earth—the sedimentary rocks, silts and clays, laid down by water. He assumed that if there could be shown any definite cyclic recurrences of dry and wet periods, of duration and importance in the life of man, such cycles would have recurred in pre-historic years. These records held by geologic formations should yield the index sought, if anything was to.

With his increasing study and observations, he became intrigued with the thought that his findings that definite cycles of weather (wet and dry periods) had been recurring during the history of hydro-geology, might be put to valuable use in predicting future weather conditions.

More exact studies seemed to yield the indices sought and led Mr. Gillette to announce his hypothesis. Based on this theory, in 1935 one of his several papers was read before the Pennsylvania Water Works Association and was printed in the Proceedings for that year. In popular slang this paper was definitely of the "neck-sticking out" variety, with some fairly definite predictions concerning weather conditions in the approaching years, based on the Gillette Weather Cycle Theory.

Many of us had considerable curiosity to see whether the "neck" of our "big-boss" (eventhough he retired some years ago to a pleasant spot in California to pursue his hobby of weather cycle studies and other things, he is still to us the "big-boss") would stick or fall. Whether it did or not is now a matter of record.

From various men of high position in the country Mr. Gillette has had letters of congratulations concerning his "Theory of Weather Cycles" and more especially his lack of temerity in publishing his predictions based on his convictions.

In the January, 1940, issue of this magazine appeared another bold prediction of near future weather conditions by Mr. Gillette in his article captioned "A Portentous Drought in the Making." An interesting side light is the fact that this paper was completed before we had entered the rather widespread drought period of the past Fall. Just how much "in the making" the drought was by publication date is now known.

This most recent paper brought to the minds of many his earlier papers, and resulted in a number of letters referring to the rather remarkable coincidence of his predictions of 1935 (Penna. Water Works Ass'n Proceedings) and actual happenings. To quote an impressive part of that paper:

"I read a paper before the American Meteorological Society, entitled 'The Cycles That Cause the Present Drought.' The paper was printed in full in the August, 1935, issue of WATER WORKS AND SEWERAGE. In that paper I gave enough evidence to establish the existence of a rainfall cycle 152 years long, which had its last time of extreme drought in 1787 and will, therefore, reach *its next extreme in* 1939. In that paper I showed that rainfall near Boston, from 1750 to 1934, gave evidence of this "grand cycle," and that the annual high-water levels of the Nile in Africa showed it since 1736. More significant than any man-kept records, like these, are the nature-kept records which tree-rings and annual silt layers in lakes furnish; for such records go back only to 1310 B. C. in the case of trees, but to 10,000 B. C. in the case of silt layers, or 'varves'."

In a recent letter to the writer Mr. Gillette has the following to say concerning years following 1940.

"The long series of droughts is still in the making, as you so aptly added to my caption. The fall of 1943 will be even drier than that of 1939 and will be followed by a very dry winter.

Since writing the 1935 paper I have found the several powerful cycles that were mentioned in my paper in your January, 1940, issue. These seem to insure an intermittent series of droughts that will reach a climax in September, 1964."

It is apparently these findings that led Mr. Gillette to state in the January article that "It need not be surprising if the great reservoir above the Hoover Dam (Boulder Dam) goes dry within the next 25 years."

In the same letter quoted above Mr. Gillette states—

"It may seem very rash to make such forecasts, but my analyses of Lake Saki varves back to 2300 B. C. give me great confidence in forecasting the effects of the cycles there disclosed. This confidence has been increased by my finding great cycles of the same lengths in rock strata, such as were shown in the half-tones in the January issue. Of course their lengths can be derived there, and it needs no analysis to disclose both their amplitudes and their rhythmic recurrence in the rocks. 'He who runs may read' these photographs of rock strata and see the answer to the question, 'Can cycles be of use in long-range forecasting.' But until Mrs. Gillette and I had measured many paired strata and varves in them, no one know the lengths of these rock strata cycles. Strange, isn't it, that neither geologists nor meteorologists had found cycle lengths of the order of those shown in the photographs in the January article."

A prominent engineer and manager of an important water utility—one who has made a study of rainfall records, looking to the future—writes in reference to the January article in *"W. W. & S."* and another in *"Roads and Streets"* for December, 1939:

"These are of the utmost value to us here in connection with our study of the variation in rainfall and making provisions for the future. Sometime, I am sure, that such will be recognized for the great scientific value which it has."

That Mr. Gillette is predicting such distressing conditions in respect to water supply (likewise sewage disposal) in this country, within the next several years, becomes the more alarming when considering the accuracy of his predictions for the 5 years preceding the widely felt 1939 drought. And, it is primarily a feeling of concern that prompts us to give heed to the possibilities and to suggest water supply planning which takes into consideration such possibilities.

L. H. Enslow

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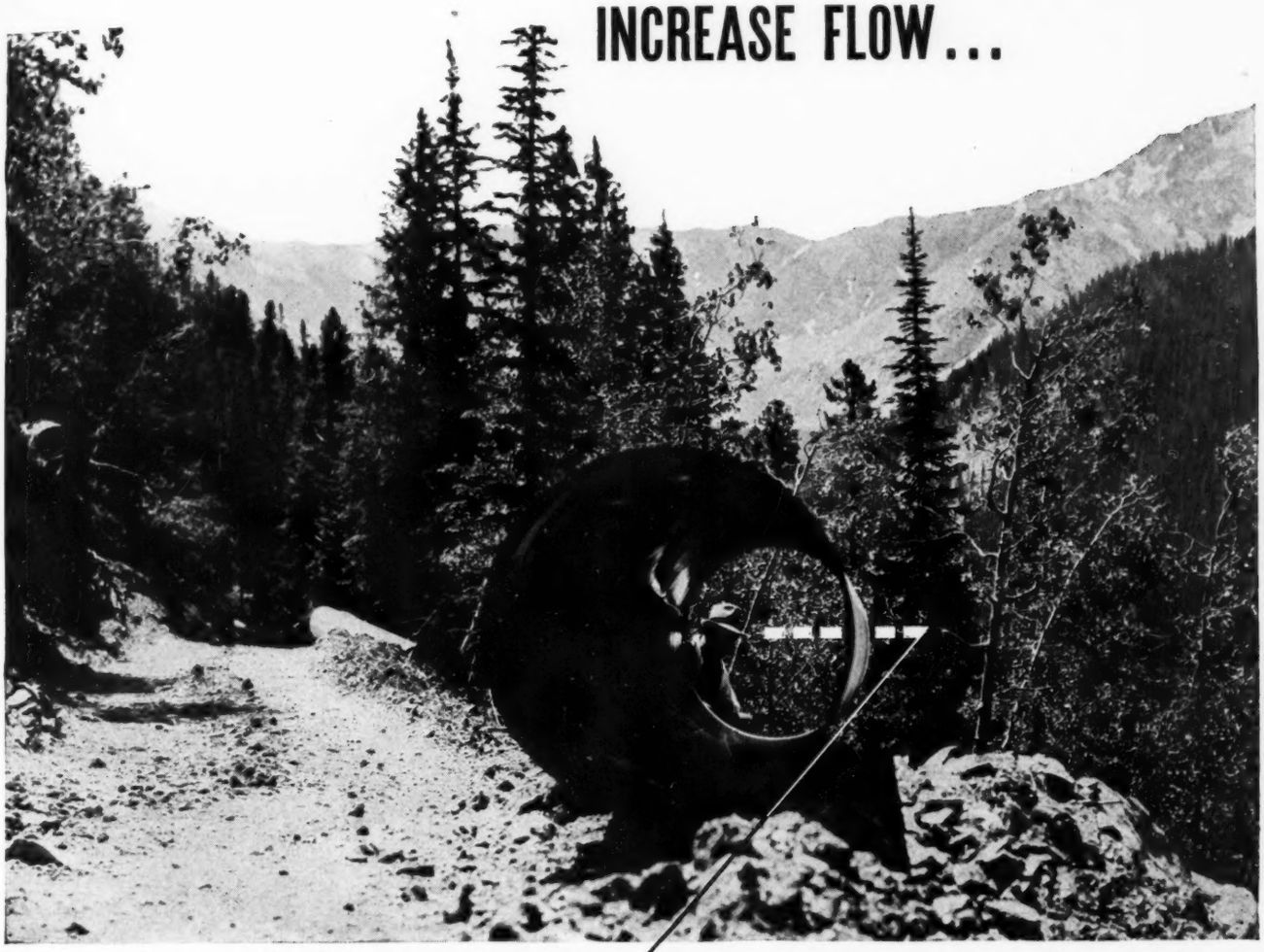

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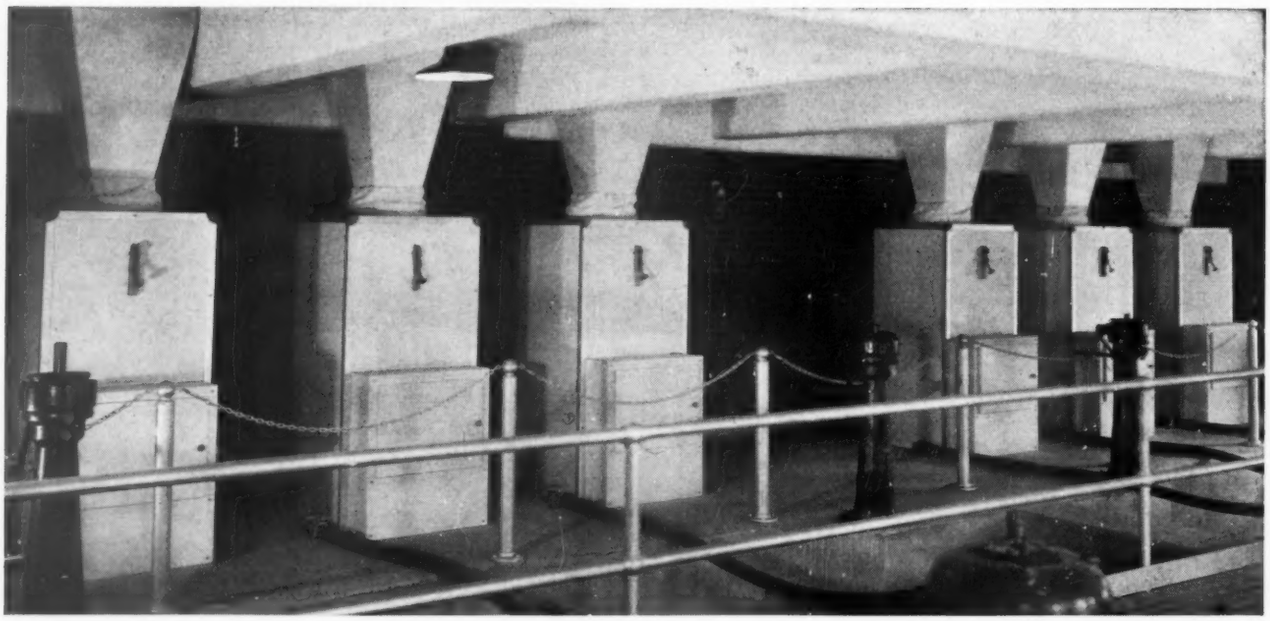

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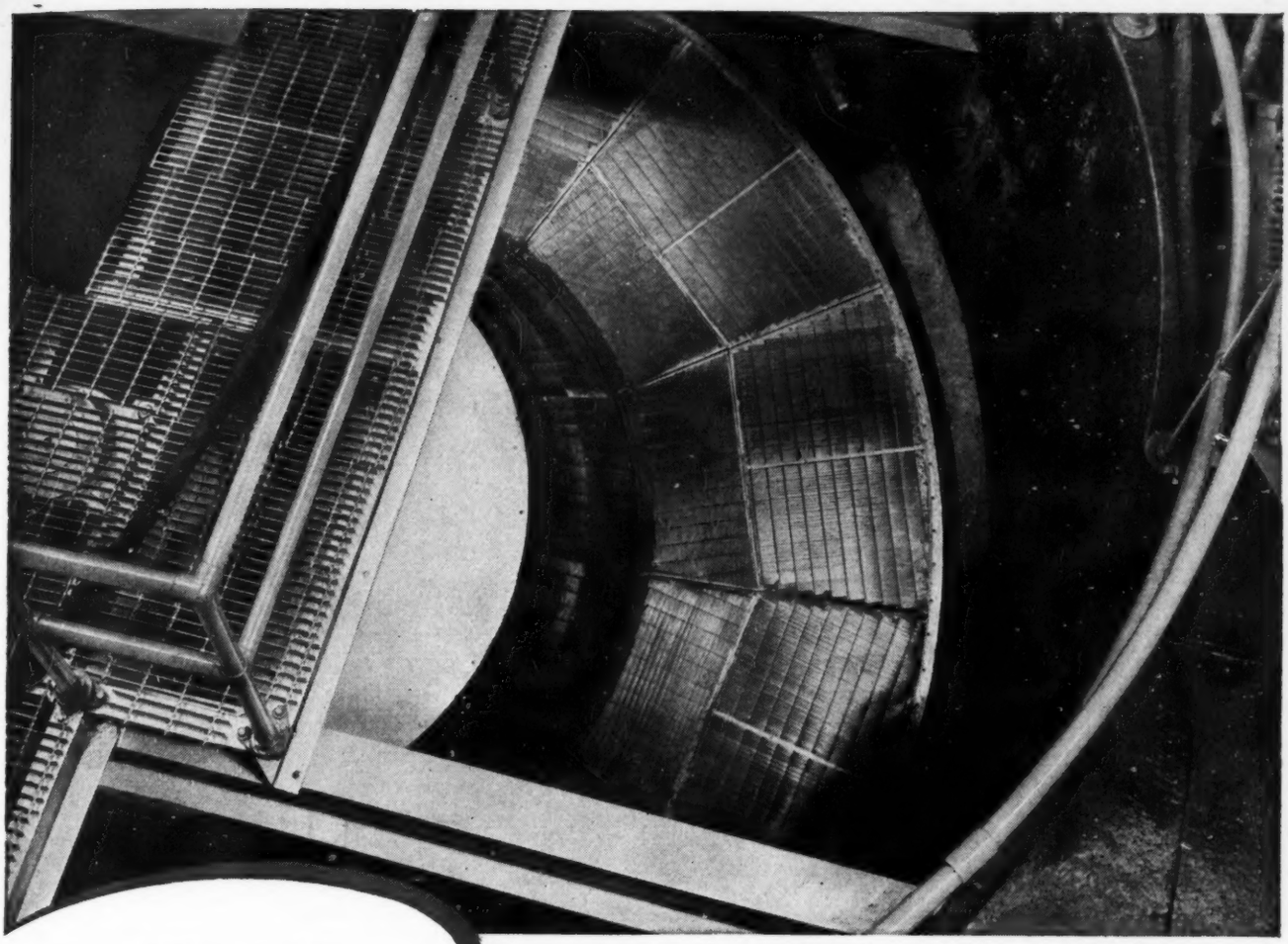

Everdur copper-silicon alloy screens in Congress Street plant of Bridgeport, Conn., Sewage Disposal System

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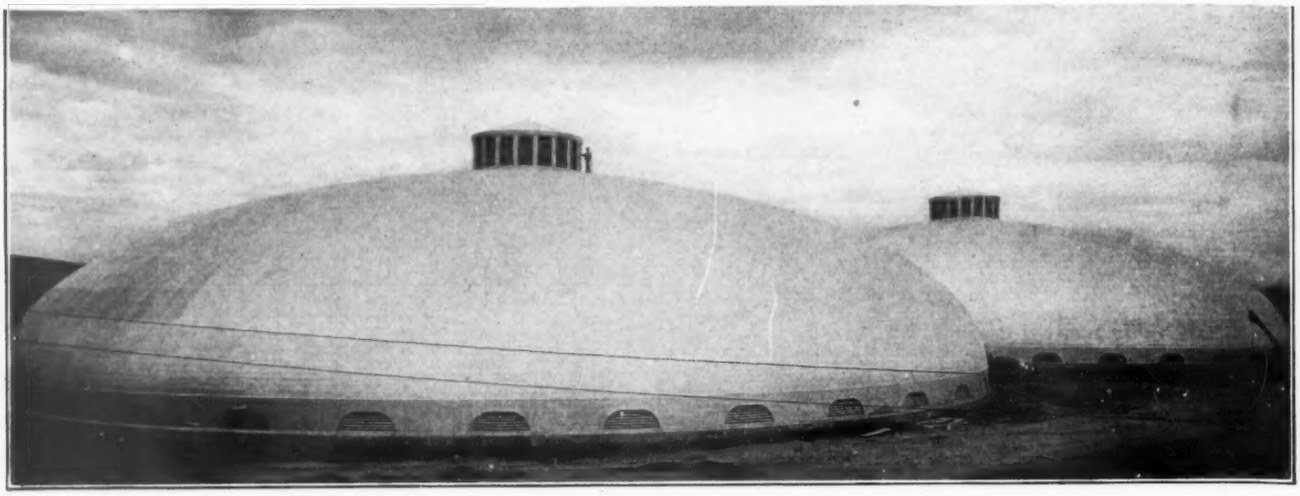

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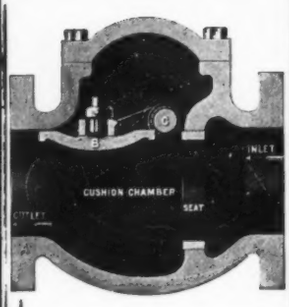

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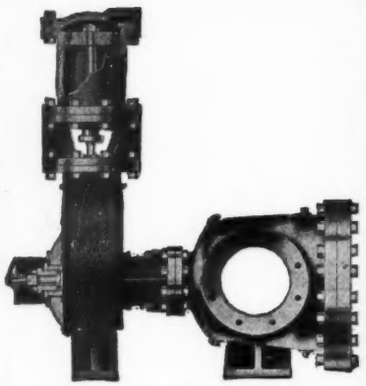

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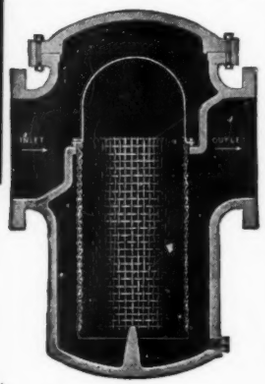

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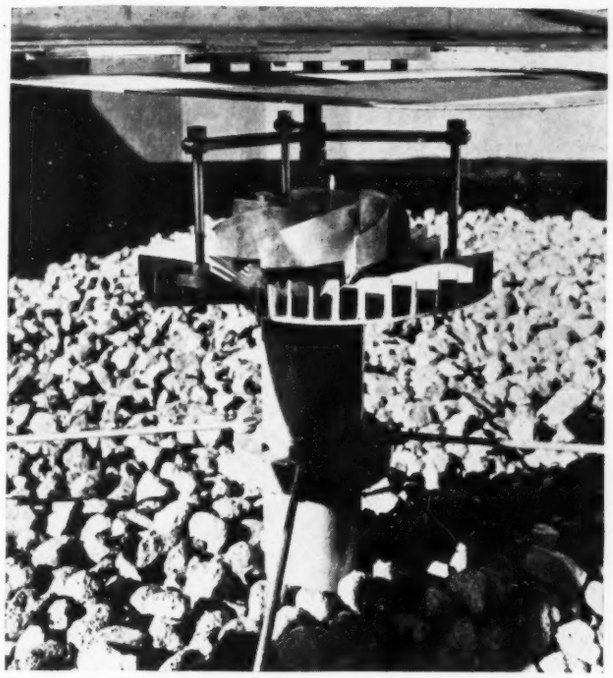

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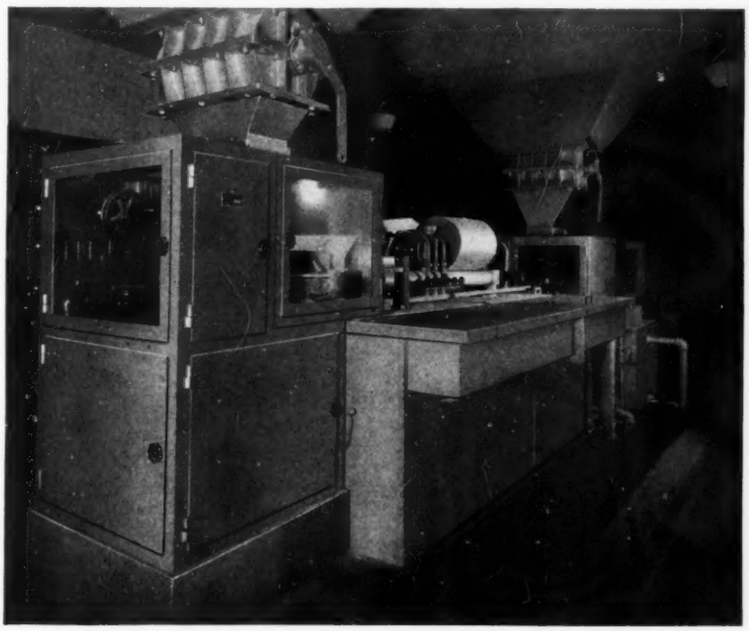

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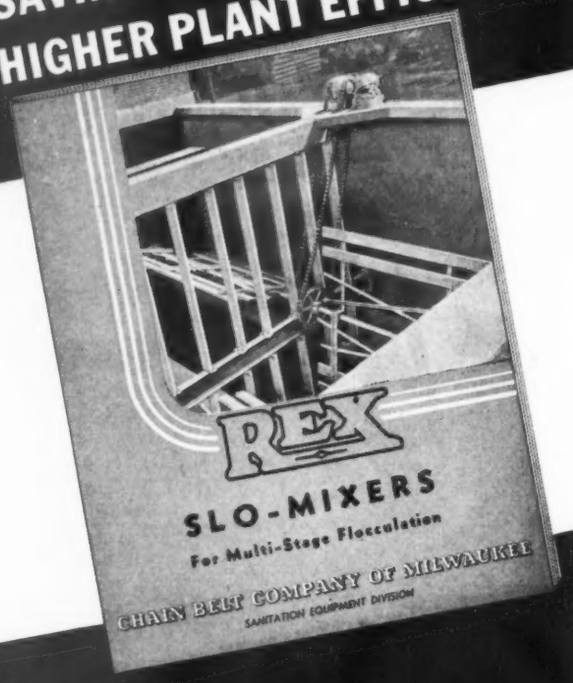

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SANITATION EQUIPMENT

MEETINGS SCHEDULED

Apr. 21-25—Kansas City, Mo. (Headquarters Hotels—The Phillips, The President and The Muehlebach)
American Water Works Association Annual Convention. Secretary, Harry E. Jordan, 22 East 40th St., New York City, N. Y.

May 8-10—East Lansing, Mich. (Michigan State College)
Michigan Sewage Works Association. Sec'y.-Treas., W. F. Shephard, State Dep't. of Health, Lansing, Mich. (Short Course to be held May 6-8).

May 8—Portland, Ore. (Portland Hotel)
Pacific Northwest Sewage Works Ass'n. (Annual Meeting) Sec.-Treas. Fred Merryfield, Oregon State College, Corvallis.

May 9-11—Portland, Ore. (Portland Hotel)
Pacific Northwest Section A.W.W.A. Secretary, Fred Merryfield, Oregon State College, Corvallis, Oregon.

May 9-10—Akron, Ohio (Mayflower Hotel)
Ohio Section A.W.W.A. Secretary, T. R. Lathrop, State Dept. of Health, Columbus, Ohio.

May 16-17—Salisbury, Md. (Wicomico Hotel)
Maryland-Delaware Water & Sewerage Associations. Secretary, A. W. Blohm, 2411 North Charles St., Baltimore, Md.

May 16-18—Jacksonville, Fla. (Hotel Seminole)
Florida Section A.W.W.A. Secretary, A. P. Black, University of Florida, Gainesville, Fla.

May 22-24—Chicago, Ill. (Congress Hotel)
Illinois Section A.W.W.A. Secretary, H. E. Hudson, Jr., 6843 Oglesby Ave., Chicago, Ill.

June 6-7—Ithaca, N. Y. (Hotel Ithaca)
New York Section A.W.W.A. (Spring Meeting). Secretary, R. K. Blanchard, 50 West 50th St., New York, N. Y.

June 12—Poland Spring, Me.
Maine Water Utilities Association. Sec.-Treas., Earle A. Tarr, Winthrop, Me.

June 20-22—Syracuse, N. Y. (Hotel Syracuse)
New York State Sewage Works Association. Sec.-Treas., A. S. Bedell, State Dept. of Health, Albany, N. Y.

June 24-28—Atlantic City, N. J. (Chalfonte-Haddon Hall)
American Society of Testing Materials (Annual Meeting). Sec.-Treas., C. L. Warwick, 260 So. Broad St., Philadelphia, Pa.

June 24-26—State College, Pa. (Nittany Lion Inn & Dormitories)
Pennsylvania Water Works Operators' Association. Annual Convention. Sec.-Treas., I. M. Glace, Consulting Engineer, 22 So. 22nd St., Harrisburg, Pa.

June 26-28—State College, Pa. (Nittany Lion Inn & Dormitories)
Pennsylvania Sewage Works Association. Sec.-Treas., L. D. Matter, Distr. Engr., Kirby Health Center, Wilkes Barre, Pa.

Aug. 14—Boothbay Harbor, Maine
Maine Water Utilities Association. Sec.Treas., Earle A. Tarr, Winthrop, Me. (Future Meetings Scheduled—Oct. 9—Millinocket; Dec. 12—Mexico).

Sept.—Wahpeton, North Dakota
North Dakota Water & Sewage Works Conference. Sec'y.-Treas., Lloyd K. Clark, Bismarck, N. D.

Sept. 11-13—Ann Arbor, Mich. (Univ. of Michigan Union)
Michigan Conference on Water Purification. Sec.-Treas., R. J. Faust, Michigan Dept. Health, Saginaw, Mich.
(Meeting Jointly with)
Michigan Section A.W.W.A. Sec.-Treas., M. N. Gerardy, 803 Water Board Bldg., Detroit, Mich.

Sept. 16-17—Denver, Colo.
Rocky Mountain Section A. W. W. A. Secretary, R. V. Howe, State Office Bldg., Denver, Colo.

Sept. 18-20—New Castle, Pa. (Castleton Hotel)
Western Pennsylvania Section A.W.W.A. Sec.-Treas., E. P. Johnson, 418 Flannery Bldg., Pittsburgh, Pa.

Sept. 24-27—New York, N. Y. (Commodore Hotel)
New England Water Works Association. (59th Annual Convention). Secretary, Frank J. Gifford, 613 Statler Bldg., Boston, Mass.

Oct. 8-11—Detroit, Mich. (Book Cadillac Hotel)
American Public Health Association. Exec. Sec'y., Dr. Reginald M. Atwater, 50 West 50th St., New York City.

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Flexible in its application—Aer-O-Mix is built in a wide range of sizes—adjustable, individual units from 50 G.P.M. to 8400 G.P.M.—with combinations to accommodate widely varying flows. Built for GRAVITY—PRESSURE—MOTOR—or PNEUMATIC operation—with surface or submerged release of entrained air or gases. A size and type to fit any existing or contemplated plant.

AER-O-MIX—an aspirating process, involving *intimate mixing* of liquids with air—gas—chemicals or other liquids.

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***IN SEWAGE TREATMENT:*—Activated sludge aeration—Trickling filter auxiliary—Pre-aeration—Post-aeration—Chemical mixing.**

Write for descriptive literature and information on your particular application or problem. No obligation.

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ALTITUDE VALVE

Controls elevation of water in tanks, basins and reservoirs.

1. Single Acting
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COMBINATION VALVE

A self contained unit, with three or more automatic controls.

Combination automatic control both directions through the valve.

REDUCING VALVE

Maintains desired discharge pressure regardless of charge in rate of flow.

Regulates pressures in gravity and pump systems; between reservoirs and zones of different pressures, etc.

SURGE-RELIEF VALVE

Maintains safe operating pressures for conduits, distribution and pump discharge.

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Maintains levels in tank, reservoir or basin.
1. As direct acting.

2. Pilot operated and with float traveling between two stops, for upper and lower limit of water elevation.

REMOTE CONTROL VALVE

Electric remote control—solenoid or motor can be furnished.

Adapted for use as primary or secondary control on any of the hydraulically controlled or operated valves.

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P. O. Box 595 Troy, N. Y.

Oct. 8-11—DETROIT, MICH.
American Public Works Association. Exec. Dir., Frank W. Herring, 1313 E. 60th St., Chicago, Ill.

Oct. 14-17—TULSA, OKLA. (Mayo Hotel)
Southwest Section A.W.W.A. Secretary, Lewis A. Quigley, 3320 W. Berry Street, Fort Worth, Texas.

Oct. 16-18—ATLANTIC CITY, N. Y. (Haddon Hall)
Pennsylvania Water Works Association. (45th Annual Meeting.) Secretary, F. Herbert Snow, 507 Telegraph Bldg., Harrisburg, Pa.

Oct. 18-19—ATLANTIC CITY, N. J.
New Jersey Section A.W.W.A. Sec.-Treas., C. B. Tygert, Box 178, Newark, N. J.

Oct. 21-23—LEXINGTON, KENTUCKY (Hotel Lafayette)
Kentucky-Tennessee Section A.W.W.A. Sec.-Treas., H. D. Schmidt, State Dept. of Health, Nashville, Tenn.

Oct. 23-26—LOS ANGELES, CALIF. (Los Angeles-Biltmore Hotel)
California Section A.W.W.A. Secretary, Burton S. Grant, 207 So. Broadway, Los Angeles, Calif.

Nov. 7-8—ST. PAUL, MINN. (Hotel St. Paul)
Minnesota Section A.W.W.A. Sec.-Treas., R. M. Finch, W. & T. Co., 416 Flour Exchange, Minneapolis, Minn.

Nov. 7-8—WILMINGTON, DEL. (Hotel Du Pont)
Four States Section A.W.W.A. Sec'y.-Treas., Carl A. Hechmer, Washington Suburban Sanitary District, Hyattsville, Md.

LITERATURE AND CATALOGS

"Selected Editorials", taken from LINK-BELT'S *NEWS* and elsewhere have been reprinted in a 64-page booklet of the size and style of *Readers Digest*. There is much good sound thinking covered in these 64 pages. Of broad general interest and mostly of a philosophical, inspirational nature, these editorials were, in the main, written by prominent authors, and first appeared in well-known magazines or newspapers; having later been reprinted in *Link-Belt News* by special permission. The editorials selected are those on which the company is said to have received many favorable comments. "Selected Editorials" is well worth the asking. For a copy write Link-Belt Co., 307 N. Michigan Avenue, Chicago.

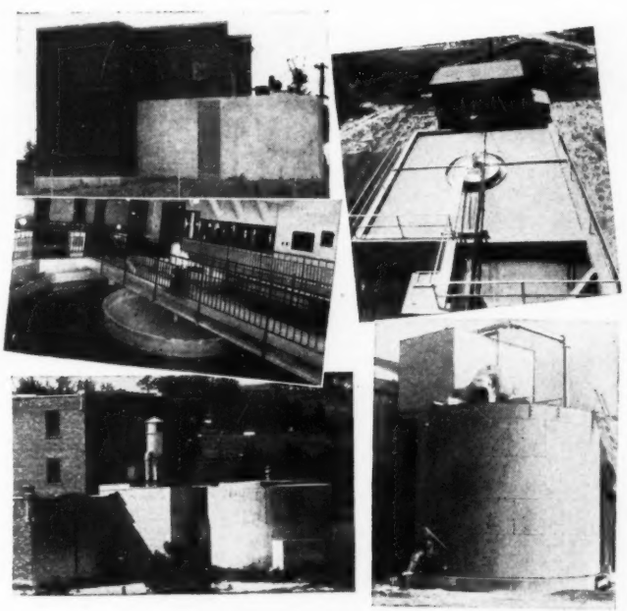
"Aero-Filters" are the subject of an impressive new bulletin from Lakeside Engineering Corp. of Chicago. The "Aero-filter", now installed in about 40 sewage treatment plants in this country, is a so-called "high-rate" trickling filter. "High Rate" is a misnomer, say the inventors and proprietors of the "Aero-filter" who prefer the term "High-Capacity" as that more truly descriptive of these units. The reason is that the load is applied at low rates (continuously or practically so) in order to secure the tremendous capacity over and above the old type trickling filters employing much higher *rates* of dosage, but with rest periods between. The new bulletin does an excellent job of explaining the attributes and advantages of the "Aero-filter", which involves adaptation of the Halvorson-Smith (patented) process. The two types of liquid distribution mechanisms, securing a high degree of uniformity of load application, are pictured and described in detail. For the smaller plants the Lakeside Motor-Driven Disc Distributor is employed; for the large units the Lakeside Multiple Arm (nozzle equipped) Rotary Distributor is employed. The latter is hydraulically or motor driven as indicated. The centrifugal type nozzles are said to operate effectively on a minimum head of 1 ft. Operating results from several representative installations and cost data are presented in confirmation of performance claims. The reader would do well to request the very informative bulletin (No. 108) on this revolutionary high-capacity process. Address Lakeside Engineering Corp., 222 W. Adams Street, Chicago, Ill.

NOW MORE THAN 100 ACCELATOR WATER CONDITIONING PLANTS

MORE THAN A HUNDRED Accelator plants for softening, clarifying and stabilizing were in service or under construction by March 1940! — 40 in the last 12 months.

The constantly growing acceptance and enthusiasm for the Accelator treating process is significant, for it indicates wide-spread *earned* approval. Through *actual performance records* in scores of installations, the Accelator has established itself as the most efficient and modern type of water conditioning plant available.

What the Accelator is, *how* it operates and *why* it has so many advantages over conventional treating plants is told in Bulletins 1820, 1821 and 1822. Let us send you copies.



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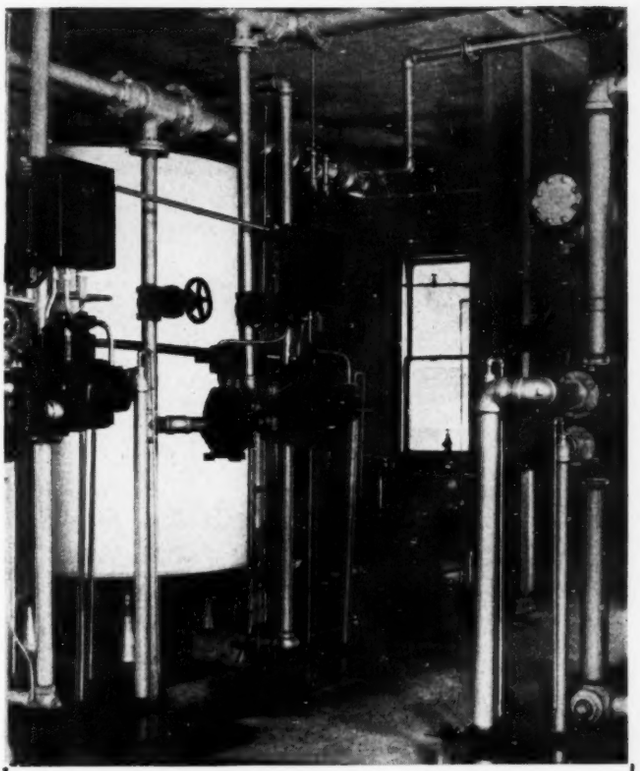

City* in Indiana Installs Permutit Automatic Zeolite Water Softening Plant

Permutit equipment installed in this modern progressive city has capacity of 177,000 gallons per day. Water hardness 25 grains per gallon is automatically softened to 5 grains.

**Name on request*

Advantages of Automatic Operation

Perhaps the biggest single feature of Permutit Zeolite Water Softeners—the feature that appeals to large and small cities alike—is automatic operation. The water works operator can attend to his other duties without unexpected interruptions. The Permutit equipment automatically cuts itself out of service, backwashes, regenerates, and returns to service.

Automatic operation also saves on salt used for regeneration. And accurate control eliminates the chance for human error. The equipment above, installed in 1939, illustrates the compact, modern simplicity made possible by automatic control.

The number of cities enjoying Permutit water conditioning is steadily increasing. How about *your* city? For further information on installation shown, booklets on municipal water conditioning, free water analysis, or advice on any water conditioning problem, address The Permutit Company, Dept. G1, 330 West 42nd Street, New York.

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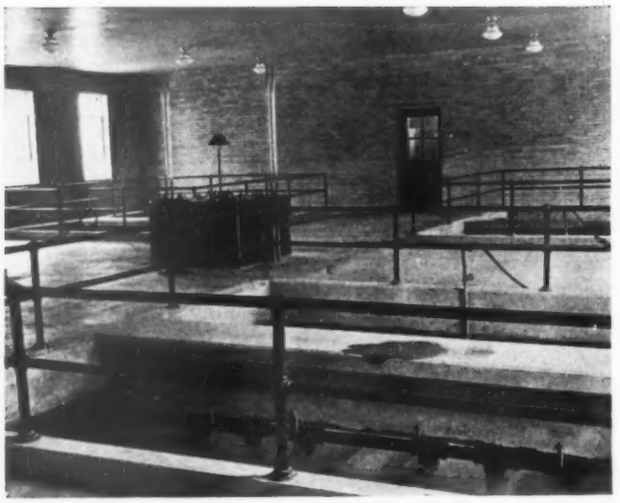

Eimco-Finlay Tunnel Loaders—are the subject of a bulletin from The Eimco Corp. which describes and pictures these compact rock and debris loaders for tunnel work. Diagrams show representative tunnels (plan and section(being put through with Eimco-Finlay Loaders, with working data cited to indicate the rapid loading and fast heading clean up performance. One tunnel of especial interest to readers of this magazine is the sewage tunnel at Lockport, N. Y. (5 ft. wide x 6 ft. high) in which electrically operated loading equipment would be dangerous, if not impossible. In addition to low cost an emphasized feature of the Eimco-Finlay Loader is its great safety—especially in wet places. These loaders are operated by compressed air motors. For additional information a copy of this bulletin can be had from The Eimco Corp., Salt Lake City, Utah, or 330 N. Michigan Ave., Chicago, Ill.

"Dualcote" is an interesting process of treating conduit and steel pipe for protection against corrosion of the most severe nature. The attributes of "Dualcote" are presented in a folder just received from Walker Brothers of Conshohocken, Penna., which states that it has successfully stopped salt water spray corrosion—hot and cold. As the name implies "Dualcote" is a combination of two coatings. First: a layer of pure zinc is actually fused (alloyed) into the walls of the steel so treated. The coating method produces a conduit which can be bent at right angles without cracking the protective galvanizing. Its surface is covered with fine teeth which grip the second (outer) protective coating which is a smooth thin "skin" of chlorinated rubber, with all of the toughness and protection against acids and alkalies that such compounds exhibit. An interesting aspect of the process is that the treads of conduits and pipes are cut on champfered ends and such threads being protected as effectively as the pipe itself. "Dualcoted" pipes and conduits are sold as such, or pipe can be shipped to the plant for "Dualcoating." For further details concerning this novel process, write Walker Brothers, Conshohocken, Penna.

"Stabilflo" Valves are presented in a new bulletin from Foxboro Co., producer of these diaphragm operated valves, featuring the "floating power" head for frictionless opening and closing; "high-lift" design for producing the marked rangeability so much desired, dual seating V-port plunger type valves. For bulletin DMF. 789 address The Foxboro Co., Foxboro, Mass.

"Automatic Priming System for Centrifugals" is a brochure from DeLaval Steam Turbine Co., which comes in the form of a reprint of an effectively illustrated article by F. S. Broadhurst, describing a fully dependable automatic priming system for centrifugal water and sewage pumps and presenting the author's experiences with it. The system keeps the pumps always filled with the liquid being pumped and thereby eliminates close operator attention. Special applications are described for individual pumps, a group of pumps using a common suction main, deep well pumps, sewage pumps, and other pumps. In all cases, with this system the water level is maintained continuously at an elevation sufficiently above the impeller suction openings so that the impeller is sealed against entry of air. An interlock prevents starting the pump until it has been properly primed, except in the case of pumps specially designed to permit running without water, as, for example, pumps driven by self-starting synchronous motors. For a copy of "Automatic Priming Systems for Centrifugal Pumps" write DeLaval Steam Turbine Co., Trenton, N. J.

"Shatter-Proof" STEEL PIPE is the Modern way of Transporting Water

The Old Model "T" was a good car in its day, but it doesn't compare with the New "V-8" with steel body and shatter-proof glass. Mains for transporting water have also improved. "Shatter-proof" STEEL PIPE is now used because it has strength beyond any possible question. When Lined and Coated-and-Wrapped by the HILL-HUBBELL "factory process" you also get PERMANENT HIGH FLOW CAPACITY.

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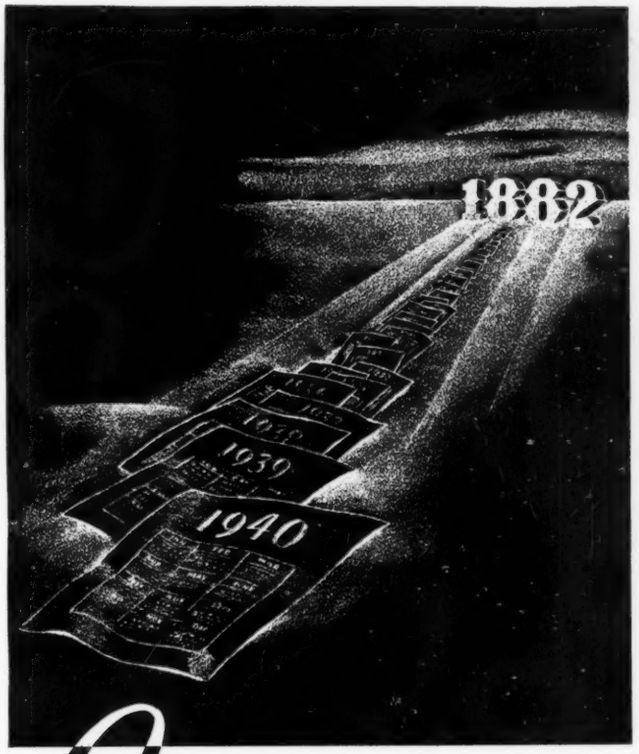

Greetings...

to the members of the American Water Works Association, in attendance at its Sixtieth Annual Convention . . . from the National Meter Company, which is proud to have had the privilege of attending fifty-nine of these meetings.

Our first association with the American Water Works Association occurred in 1882, when this Company was elected to membership. At that meeting Mr. John C. Kelley, Founder and First President of the National Meter Company, read what was then a revolutionary paper on the subject of water meters. A facsimile copy of this historic paper is obtainable at the National Meter Company's booth—Nos. 72 and 73—together with a new booklet, "Revolutionary? Of course it was!"—which tells about the birth and growth of the water meter industry National Meter Company, 4259 First Avenue, Brooklyn, N. Y. Branch Offices in Boston, Chicago, Dallas, Los Angeles, San Francisco, Seattle.

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MUNICIPAL WATER SOFTENING PLANT	Ames, Iowa
LEMIEUX ISLAND FILTRATION PLANT	Ottawa, Ontario
MAHONING VALLEY SANITARY DISTRICT	Niles, Ohio
MUNICIPAL WATER PLANT	Columbus, Ohio
MUNICIPAL WATER PLANT	Peru, Ill.
U. S. GOVERNMENT FILTRATION PLANT	Ft. Leavenworth, Kans.
MUNICIPAL WATER PLANT	Hamilton, Ohio
BACHMAN WATER PURIFICATION PLANT	Dallas, Texas
MUNICIPAL WATER PLANT	Richmond, Va.
MUNICIPAL WATER PLANT	Springfield, Ill.
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MUNNICIPAL WATER PLANT (2 installations)	Milwaukee, Wis.
MUNICIPAL SEWAGE DISPOSAL PLANT	Oklahoma City, Okla.
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MUNICIPAL SEWAGE DISPOSAL PLANT	Detroit, Mich.
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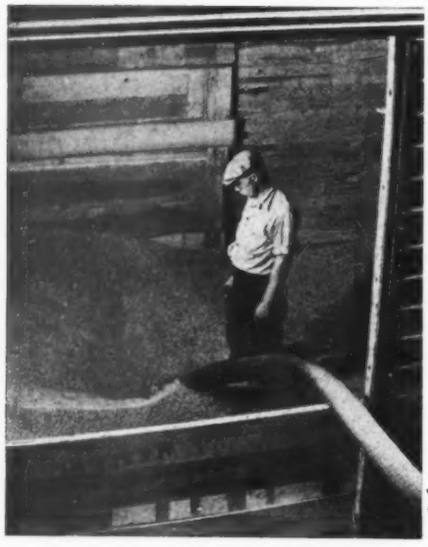
CITY OF TORONTO WATER WORKS PLANT	Toronto, Ontario
WATER FILTRATION PLANT	Ottawa, Kansas
EL RENO WATER TREATMENT PLANT	El Reno, Oklahoma
CITY OF GRAND FORKS	Grand Forks, NoNrth Dakota
MUNICIPAL SEWAGE PLANT	Pittsburgh, Pennsylvania
WATER FILTRATION PLANT	Wichita, Kansas



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"Some Painting Problems and Answers" is a reprinted article bearing this caption. The author is F. L. Brown, Senior Chemist, Forest Products Laboratories, who discusses "The Cure for Mistakes in Applying Paint," "Mistakes in Paint Maintenance," and desirable and undesirable characteristics of paints commonly used. This reprint and others of similar nature are being distributed by Lead Industries, Inc., 420 Lexington Ave., New York City. Copies are available for the asking.

A New Tanktrol Bulletin represents the first of the revised bulletins under production and distribution by Automatic Control Company of St. Paul. Along with it comes a folder for filing this and forthcoming bulletins. It is noted that the various types of Tanktrol units for controlling pump operations have had their designating letters changed in several instances. Also a new inexpensive Tanktrol unit (Type ES) has been added. This compact unit automatically cuts out a single pump (started manually) when the reservoir or tank level reaches a selected elevation. On the file folder appears a rapid glance index of "Tanktrols," "Floatrols," "Selectrols," "Duotrols," etc. The revised bulletin is a definite improvement over the earlier issues. For a copy of the 1940 edition, address Automatic Control Co., 2590 University Ave., St. Paul, Minn.

All Service Separators by Cochrane are presented in a new 8 page bulletin from Cochrane Corp. of Philadelphia. These baffle type separators are designed for installation in vertical or horizontal lines for the purpose of separating moisture, oil and foreign matter from steam, gas and air. Illustrated, with sectional views and completely described, are the three popular types available for lines ranging from ½ to 30 inch diameter. The design is backed by 50 years of experience. Data on proper drainage, gage fittings and auxiliary equipment is also given. These separators have large capacity trapping reservoirs to hold the separated materials. For a copy of "All Service Separators" write Cochrane Corp., Philadelphia.

M.S.A. Oxygen Breathitg Apparatus is dealt with in a Mine Safety Appliance Co. bulletin which announces the new light weight One-Hour Back Type Model. The new model operates on the same principles as the M.S.A. Front Type Model. The 24 pound unit has a strong aluminum cover and wide web strap harness. Either a mouth-piece or a full face piece is furnished. The Back Type Model was designed to allow more freedom by the wearer. For Bulletin B.M.-2, write Mine Safety Appliance Co., Pittsburgh, Pa.

"Hose Hints" is the caption of a new 34 page bulletin from U. S. Rubber Co. which contains handbook information of value to all concerned with the purchase, use and maintenance of hose. The prospective buyer making use of "Hose Hints" is enabled intelligently to select the proper type and grade of hose to best meet his requirements. The user of hose will find in "Hose Hints" many suggestions of how to get the longest and most trouble-free service from hose. Cutaway views of typical hose sections, accompanied with brief descriptions, give the reader a clear picture of the variety of hose available. The same treatment is given the several types of hose fittings and couplings. The Chapter "Hints for Hose Users" contains valuable "dos and don'ts" in using, handling and storing rubber hose. The last 5 pages are devoted to tables of useful information to hose users. For a copy of "Hose Hints" write, U. S. Rubber Co., Rockefeller Center, New York City.

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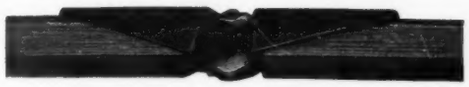

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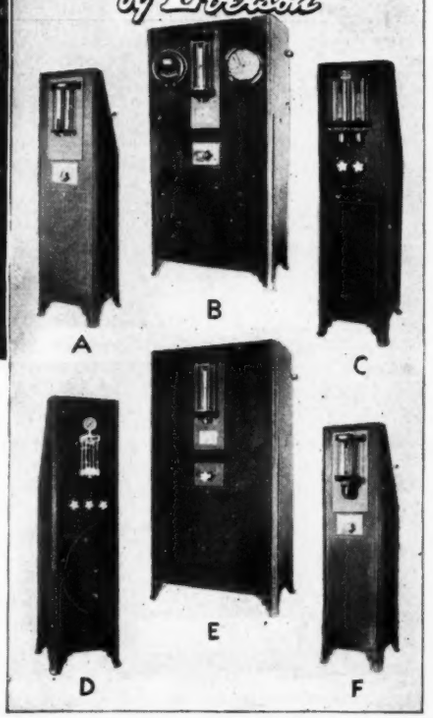

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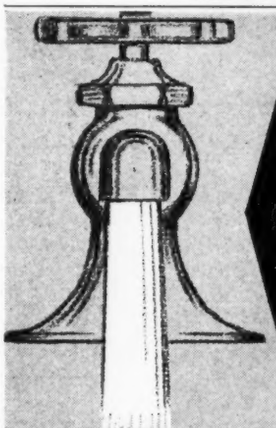

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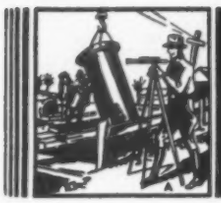

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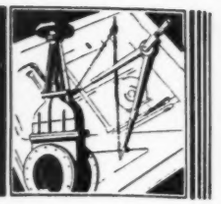

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Place your professional card in this Directory of Consulting Engineers where it will be seen when the readers are seeking your services. Rates nominal. Write
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The RUSTOP System

. . . a definite saving to Water Tank Owners

WHAT IT IS

The RUSTOP System is the cathodic system of preventing underwater corrosion of steel storage tanks. It consists of a rectifier, anodes of suitable material, the necessary meters, wiring and other incidentals.

WHAT IT DOES

The RUSTOP System definitely inhibits the corrosion of steel under water in elevated tanks, standpipes, hot water storage tanks, filter plants, condensate tanks and similar vessels affected by oxidation.

The RUSTOP System cleans off all rust, scale and corrosion products, and protects the metal from any further oxidation. This protection continues as long as the System is used. On new tanks, the protection starts as soon as the water is first put in the tank. The tank walls, bottom and riser will remain free of any corrosion.

HOW IT WORKS

The RUSTOP System maintains the tank in a cathodic condition as long as the System is used. Before an installation is made on any tank, all factors such as size and shape of tank, character of water, method of use, etc., are taken into consideration. The RUSTOP System is then engineered for that specific tank. A long-lived rectifier (some on similar service have lasted 25 years) of the proper size and type, with the size, number and types of anodes for the right distribution are recommended. It is only by such engineering that complete protection, free from localized corrosion, can be obtained.

WHAT IT COSTS

The cost of the RUSTOP System depends on the size and shape of the tank, etc. In the vast majority of cases, the first cost is less than what it would cost to paint the tank twice. And besides, use of the tank is not interfered with for one moment. The water is not contaminated nor is the taste affected.

Current consumption is not a great item. Since the voltage and amperage are low, the cost may vary from a few cents a month to a few dollars per year, depending on the size of the tank.

If you attend the Convention at Kansas City, be sure to look us up in Booth No. 16. We shall be glad to explain the RUSTOP System to you in person.

ELECTRO RUST-PROOFING CO. ● Third National Building, Dayton, Ohio

Elevated water storage, properly located, is an essential of the modern water system—insuring good service to the consumer and economical operation in old or new systems. P·DM Elevated Steel Tanks will give your community these and many additional benefits—*at lower cost.* We'd like to tell you of them! Meantime write for Bulletin No. 101.

PITTSBURGH · DES MOINES STEEL COMPANY

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SAVE Money, Time, Labor and Equipment with

UNIVERSAL CAST IRON PIPE

LAID WITH ONLY WRENCHES →

NO CAULKING MATERIALS →

NO GASKETS. NO BELL HOLES TO DIG. NO LEAD →

For water supply, fire protection systems, sewage disposal systems, industrial, and irrigation. Flexible. Tight joints.

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Gentlemen: Send us information and catalog on UNIVERSAL CAST IRON PIPE.

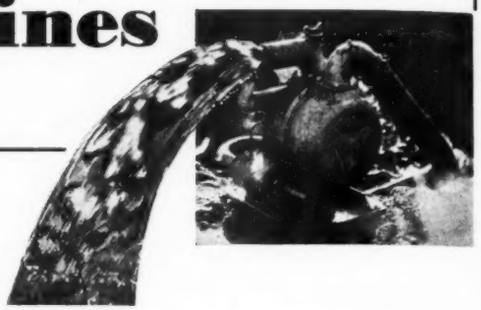
NAME .....

STREET .....

CITY .....

WHEN THE RAIN POURS—

A Homelite Shines



A bright spot in your rainy season is a Homelite Portable Pump. It does your pumping quicker, with less trouble, and at lower cost. Being easily portable—only 91 pounds complete with built-in gasoline engine—it is rushed from job to job in breath-taking speed. And with its 15,000 gallons per hour capacity, your pumping is over quickly.

Added to this, the Homelite gives you fast self-priming, automatic seepage control, 28-foot suction lift, a 70-foot pressure head, and non-clogging performance even when handling 35% solids.

Send for bulletin that shows why Homelites give you more pumping per dollar.

THE HOMELITE CORPORATION
2504 Riverdale Avenue **Port Chester, N. Y.**

Ford water meter Testing Machines and Calibrated Tanks are made in sizes for various requirements. They provide maximum convenience and accuracy and are moderate in cost. All Ford Testing Machines can be equipped with the Testerate Indicator. Write for Catalog 38.

FORD METER BOX CO.
WABASH, INDIANA

EQUIPMENT NEWS

New Remote Liquid Level Indicator Has Novel Features

● Electric Indicator Co. of Stamford, Conn., announce a new electrically functioning Remote Liquid Level Indicating System, which possesses novel features and is nominally priced.

"ELINCO" Liquid Level Indicators are offered for use in conjunction with elevated tanks, reservoirs, filtration plants and sewage works — or wherever remote indicating, recording or control of liquid elevations is desired.

The principle of operation is the well established self-synchronous motor principle which provides ruggedness without sacrifice of sensitivity or accuracy. The transmitting and indicating (receiving) units may be separated any distance for which electric wiring is available or can be provided.

Voltage and frequency variations have no effect on the accuracy of the "ELINCO" System and another attribute is the fact that if electric current is interrupted temporarily the units automatically return to service upon resumption of current flow. In this, there is no loss of accuracy or need for manual re-setting of any sort.

The Type W-1 Transmitter Unit, in an aluminum case, is completely weather proof, and therefore suitable for outdoor locations without protective housing. The Liquid Level Indicator is designed for flush panel mounting in square or round frames. Standard dials of aluminum are calibrated for ranges of 5, 10, 20 or 30 feet in level variations. The indicating unit and the transmitting unit are equipped with the dependable "Elinco Midget" synchronous motors.

The transmitter unit makes use of counter-weight on an 8½" diameter seamless copper float suspended from a corrosion proof chain which operates the bronze sprocket and shaft of the transmitter. At slight extra cost Monel metal or stainless steel parts may be had when specified.

At this writing we regret that no illustrations of the new ELINCO Indicator units are at hand and we would suggest requesting a copy of the new brochure of which we have been supplied proofs only. It gives adequate details. For a copy of Bulletin W-130, write Electric Indicator Co., Stamford, Conn.

New Vibration Dampener By J-M

● An easily installed vibration isolator, designed to economically control machine vibration and reduce the resulting noise, is a new Johns-Manville product. The device, known as the J-M Controlled Spring Isolator, was developed for use on the bases of motors, generators, pumps, compressors, air blowers, gas or Diesel engines, etc., where vibration and excessive motion create noise, tend to wear out machine parts and do additional damage.

The working parts of the unit (see cutaway view) consist of a coil and a rubber

OFFERS a COMPLETE LINE for Waterworks Filtration and Sewage Disposal Plants

Fig. 67

The M. & H. complete line includes: Gate Valves — Check Valves — Valve Boxes—Fire Hydrants—Mud Valves—Shear Gates—Extension Stems — Floor Stands — Tapping Sleeves and Valves — Cutting-In Tees—Flanged Fittings, also Special Fittings for Filtration and Sewage Disposal Plants.

M. & H. Valves and Fire Hydrants conform to the latest specifications of the A.W.W.A., as well as approved and listed by Underwriters and Factory Mutuals.

Write today for a copy of our new catalog. Just off the press.

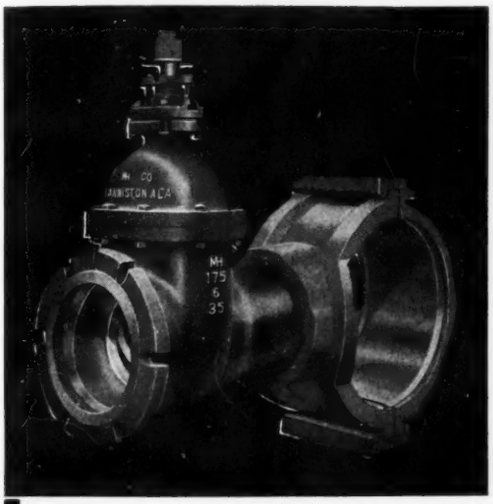


Fig. 72-73

JUST OFF THE PRESS! our NEW CATALOG now ready

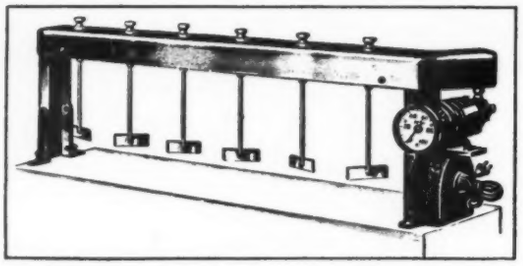
M. & H. VALVE & FITTINGS CO.
ANNISTON, ALABAMA

GOOD MIXERS . . .

in the

WATER WORKS FIELD

"Bob" Haywood of Industrial Chemical Sales—"Fred" Stuart, President, Activated Alum Corp.



THE *Phipps & Bird* LABORATORY MIXER...

IS the important piece of equipment in the Modern Water Works Laboratory. Now being used by leaders in water works research. Many superintendents and chemists have been able to reduce their chemical costs by the control of this mixer—dry feed machines adjusted accordingly.

The Phipps & Bird Laboratory Mixer makes longer filter runs possible, together with reducing wash water consumption. All alert Water Works Superintendents and Chemists should "tie" in this Mixer with modern plant practice.

Send for Literature

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RICHMOND, VA.

"SOUTHERN CENTER FOR LABORATORY APPARATUS AND CHEMICALS"

84" pipe—Spring Lake, N. J.

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Large stock enables us to make prompt shipments.

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SIZES 2" TO 84"

Warren Foundry & Pipe Corp.

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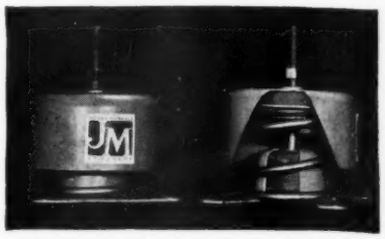
Warren Pipe Company of Mass., Inc.

75 Federal St., Boston

load pad, which support the equipment and isolate vibration. An adjustable rubber snubber, inside and base, controls excessive motion. Through the combination of these



parts, the manufacturer states, the isolator provides both the high compliance necessary for good dampening and the control needed to limit motion in the equipment.

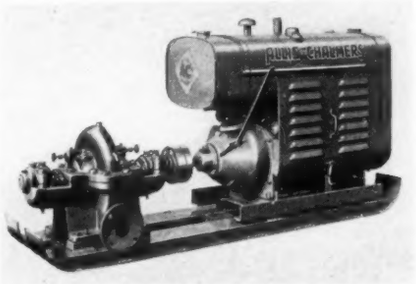
The Isolator was built to take care of horizontal and torsional as well as vertical vibration. Tests by the J-M Research Laboratories, where the unit was developed, indicate it also to be particularly efficient for the low frequency vibrations resulting from slow speeds and from many operations involving reciprocal action. The load pad is designed to overcome any high frequency vibrations.

The isolator is made in two sizes: Light Duty, for loads from 60 to 190 lbs. per isolator; and Heavy Duty, for loads from 250 to 720 lb. per isolator. Heavy machines may be isolated by clusters of the units. The loaded overall dimensions of the isolator are 6"x6" by approximately 3¾" high. It is enclosed in a metal jacket which protects the rubber parts from oil and light.

For more detailed information write Johns-Manville, 22 East 40th St., New York City.

New Engine Driven Centrifugal Pump

A line of centrifugal pumps driven by gasoline power units has been brought out by Allis-Chalmers Mfg. Co., Milwaukee, Wis. Power units in five sizes (18 to 110



Engine Driven Centrifugal Pump Unit

H.P.) assure economy in operation with a choice of fuels; gasoline, kerosene, distillate, natural gas, or butane. All power units have valve-in-head medium speed engines, with removable cylinder liners, efficient cooling systems, force feed lubrication and a variable speed governor. The centrifugal pumps are horizontal shaft, single stage, single or double suction pumps desgined for handling liquids at normal temperatures with maximum efficiency. To facilitate handling, the engines and pumps are mounted on a base and are available in many combinations to meet various requirements in quantity and pressure up to 5,000 gal. per minute and 100 ft. head.

F.-M. Develops New Line of Two-Stage Pumps

● To fill the demand for better pumping equipment at head conditions above the range of single stage types, Fairbanks-Morse has developed a line of two-stage, split-case pumps with capacities up to 550 G.P.M. at heads ranging up to 600 feet.

The new design (Fig. 5972) incorporates numerous features which contribute to operating efficiency and long service life. The two one-piece impellers are mounted "back to back" on the shaft to secure the hydraulic balance which is said to result in superior pump performance. Removable wearing rings, with streamlined water guiding surfaces, are provided on both casing and impeller. The shaft, made of high manganese alloy steel, is journaled in ball bearings of ample size to withstand all thrust and radial loads. Centrifugally-cast bronze shaft sleeves are mounted on the shaft to protect it against abrasive or corrosive action of the liquid.

Horizontally divided glands of bronze facilitate removal and adjustment of packing. Stuffing boxes are especially deep, to accommodate an adequate supply of packing rings. A bronze water-seal ring in the stuffing box on the low pressure stage prevents air entry and consequent reduced efficiency.

Bulletin 5972 describes these pumps very completely. For a copy write Fairbanks-Morse & Co., 600 So. Michigan Ave., Chicago.

Turco Windlass Truck

● Turbine Sewer Machine Company of Milwaukee have just announced a new Windlass Truck in response to demands for a unit which has its several advantages in sewer cleaning operations.

This small reasonably priced two-wheeled truck is strongly built and perfectly balanced. It has Alemite lubricated roller bearings and rubber tired wheels. One man can now pull either the Type A Double Geared Windlass or the Type B Turbine Junior Windlass very readily from manhole to manhole.

This advantage permits sewer cleaning to progress without holding an automobile truck on the job to move the heavy equipment. And, the manufacturer emphasizes the ruggedness of this new truck and its great ease of handling on the job. Also, its inexpensiveness.

For more complete information write Turbine Sewer Machine Co., 5210 W. State Street, Milwaukee, Wisc.

Has Your City Money to Burn?

Royer "Jr."—one of twelve models—eliminates incineration costs and makes profits instead for a Wisconsin city.

No city has money to burn *today*—yet when you incinerate, bury or dump sewage sludge, it's like burning money because dried sewage sludge has a real cash value when properly prepared for marketing as fertilizer with a Royer Sewage Sludge Disintegrator.

Wide awake operators of sewage treatment plants in many states are realizing a worthwhile profit from the sale of sludge that formerly cost them many dollars to dispose of.

The Royer shreds, mixes and aerates sludge with a moisture content as high as 51%, further drying it, and discharges the finely shredded product into trucks or wagons. It thoroughly mixes in lime, ammonium sulphate or other enriching materials which further increase the market value of the sludge.

There's a market for your sludge within an hour's drive of your plant—all you can produce. Get the complete facts on what other plants are doing, how to capitalize on a brand name and *new* bulletin showing 12 models, from $250.00 up; gas engine, electric motor and belt-to-tractor driven.

ROYER FOUNDRY & MACHINE COMPANY

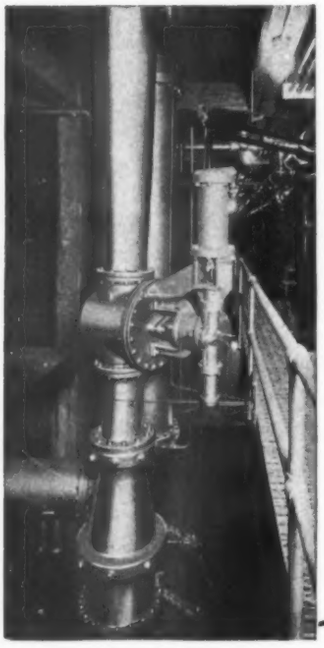
170 Pringle Street, Kingston, Pa.

THE ROYER

Which Primary Element?

VENTURI TUBE, FLUME, WEIR,

ORIFICE, OR NOZZLE



The primary element for your metering application should be selected not arbitrarily but by the requirements to be fulfilled and by the economic considerations entering into the installation.

Sewage and sludge are often, though not always, measured by Venturi Tubes, Flumes, or Weirs.

Water may be satisfactorily measured by any type of primary element. Factors such as the cost of pumping, the pressure and the size of pipe or channel usually dictate the device used.

Steam is usually measured by the Bailey Orifice or Flow Nozzle.

Bailey Meter Company holds no brief for any particular primary element, its only interest is in making sure that the user secures the highest accuracy and reliability at the lowest expense.

Detailed information on the advantages of various types of primary elements furnished on request.

MU-18

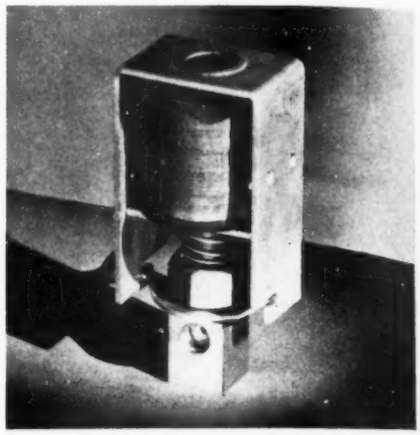
BAILEY METER COMPANY

1072 IVANHOE RD., CLEVELAND, O.

Bailey Meter Company Limited, Montreal, Canada

G-E Solenoid Valve

● General Electric Co. has developed a low cost solenoid valve for general applications in the control of water, air, gas, oil. It may be employed in a variety of uses in the water and sewage fields for start-stop operations, involving water pressure or compressed air. It is also useful in pilot gas control for gas burning equipment; for timed intermittent water sprays, opening hydraulic valves, etc.



Since it is intended for use in an assembly having its own enclosure, no coil cover, etc., has been provided, as is indicated in the accompanying picture.

For further details write General Electric Co., Schenectady, N. Y.

A New Idea In Water Practice

✦

Prevent excess aquatic plant life in feeder lakes with

BENOCLOR 3.

Weeds that never grow cannot deplete oxygen late in the summer.

✦

Let us give you full information

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CLOROBEN CORP.

90 Forrest St. Jersey City, N. J.

FERRIC ISCO CHLORIDE

For Sewage and Water Treatment have you tried

• ISCO •

Ferric Chloride . . . . . SOLUTION or CRYSTAL?

FOR SLUDGE CONDITIONING—Ferric Chloride is accepted as the agent most efficient from the standpoint of performance and cost.

FOR COAGULATING SEWAGE—Ferric Chloride provides an inexpensive and effective method of dealing with plant overloads.

FOR WATER PURIFICATION—Ferric Chloride is an economical and practical coagulant, and gives quick-forming, fast-setting floc. Write

INNIS, SPEIDEN & CO.

117 LIBERTY STREET, NEW YORK, N. Y.

Chicago Cleveland Boston

Philadelphia Gloversville, N. Y.

Buchner Funnels of Stainless Steel

● To meet a demand for a trim, lightweight, non-destructible Buchner Funnel for sewage and water laboratories, The Chemical Rubber Co. of Cleveland, Ohio, are offering such funnels (especially useful in sewage laboratories) fabricated of stainless steel.

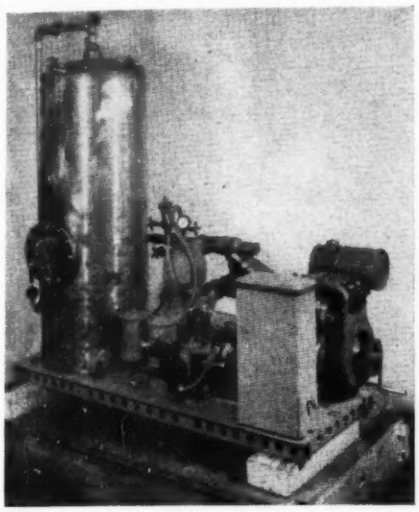
The funnel has a perforated bottom plate and solid side-walls of 24 gauge plate. The weight in comparison to the cumbersome porcelain Buchner Funnels is not given in the literature; however, anyone who has tipped over a top-heavy filter flask-funnel assembly will appreciate the new light weight stainless steel lifetime funnel.

For further information concerning the No. 5900-A funnel, write The Chemical Rubber Co., 1900 W. 112th St., Cleveland.

Portable Filter Plant of Watch Fob Proportions

● Following the style trend of the famed "Little Red Pumps" %Proportioneers%, Inc., have produced not much more than a "hand-full" of complete treatment plant for portable or temporary use. The whole unit, pictured here, weighs but 700 pounds and fits into a dry-goods box.

The new assembly, dubbed the PUR-O-PUMPER, consists of a gasoline engine driven American-Marsh Turbine Pump (self-priming); three truly watch-fob sized "Little Red Pumps" to feed (proportionally) high-test hypochlorite, alum and soda-ash; and a pressure sand filter—all being connected by use of flexible hose. A filter by-pass permits higher rates of delivery if required.



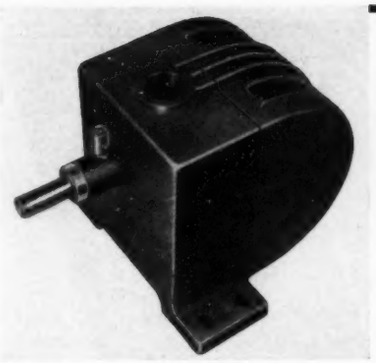
The unit here pictured, with a filtering capacity of almost 20 g.p.m. (40 g.p.m. when bypassing)—was built to meet U. S. Army specifications for mobile service and temporary locations. %Proportioneers% announce that this "Standard Package" treatment unit is to be available in capacities both higher and lower than the Army units, for supplying camps, resorts, contractors, or small towns finding an emergency supply a temporary necessity. It is certainly nominally priced and should serve a very useful purpose.

For descriptive literature on the "PUR-O-PUMPER" write %Proportioneers%, Inc., 9 Codding St., Providence, R. I.

Everson Automatic "Sterelator"

● Everson Manufacturing Co. of Chicago has recently announced the addition of a fully automatic "Sterelator" to the Everson line of chlorinating equipment. The new Sterelator (No. 2700) not only automatically proportions the feed of chlorine to the rate of flow, but at the same time records the flow of the water or sewage being treated. The information received is a bare announcement of the new automatic unit, and no details given.

For further information, write Everson Manufacturing Co., 214 W. Huron St., Chicago, Ill.



Transmitter

FROM HERE

"ELINCO" Remote Liquid Level Indicator

FILTRATION and sewage disposal plants, stand pipes, reservoirs, tanks, etc., are but a few of the many places where the "Elinco" Remote Liquid Level Indicators are a time-and-trouble-saving necessity. Actual levels at one or more points—100 yards, a block or a mile from the point at which the "Elinco" Transmitter is located—can be instantly determined by a glance at the "Elinco" Indicator.

These instruments are easily installed and function automatically at the slightest change in level.

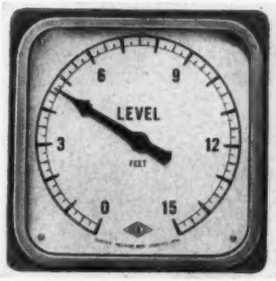
The NEW "Elinco" simplified system operates on the self-synchronous motor principle. By standardizing on various ranges of levels the cost has been reduced to a minimum.

Write for your copy of Bulletin W-130 for complete information.

ELECTRIC INDICATOR CORPORATION
STAMFORD, CONN.

TO HERE

Indicator



HYDRO-TITE

ONE POUND does the work of four pounds of lead. Much easier to use than lead and requires no caulking.

HYDRO-TITE joints are strong, very flexible and tight.

Write for our free trial offer.

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GENERAL OFFICES AND WORKS - WEST MEDFORD STATION
BOSTON, MASS.

OVER 25 YEARS WITHOUT A FAILURE

Sewage-Water Treatment

CARTER

Sludge Pumps
Floc Formers
Chemical Mixers
Sludge Mixers
Alternating Syphons
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Self-priming Centrifugal Diaphragm

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RALPH B. CARTER CO.

Engineering Offices
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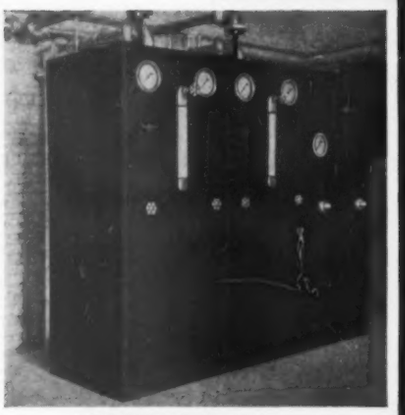
Main Office and Factory
195 Atlantic St. **Hackensack, N. J.**

CHLORINATORS AMMONIATORS

by PARDEE



Two 2000 pounds per day full automatic vacuum solution feed Chlorinators, with electrically operated 6000 pound Evaporator, at the Wyandotte, Michigan Sewage Disposal Plant.

THE PARDEE ENGINEERING COMPANY • LONG ISLAND CITY • NEW YORK

PHOENIX
DISC WATER METERS

Are proving their true economy to exacting Water Superintendents.

SPIRAL GEARS—Just as the Automobile Industry uses Spiral Gears in the Car you drive, to eliminate friction and obtain smooth quiet operation, we employ Spiral Cut Gears and have obtained the same results. Spiral Gears are a patented feature in Phoenix Meters.

Let us show you point for point, just how Phoenix Meters can and will prove to be a truly economical Meter.

UNION METERS—Did you know we furnish Repair Parts for Union King Meters formerly manufactured by the Union Meter Company. Write us for prices on our Repair Parts.

PHOENIX METER CORPORATION
Established 1914
Prince Bay, S. I.
New York, N. Y.

Tested
Protective Bituminous Surfacing Products

HYDRO PROOF
For surface repairs and protection on all reservoir tops and walks and on floors of every nature.

HYDRO PROOF Plastic
Fine quality plastic joint material for sewage pipes. Saves both time and money in the production of tight joints.

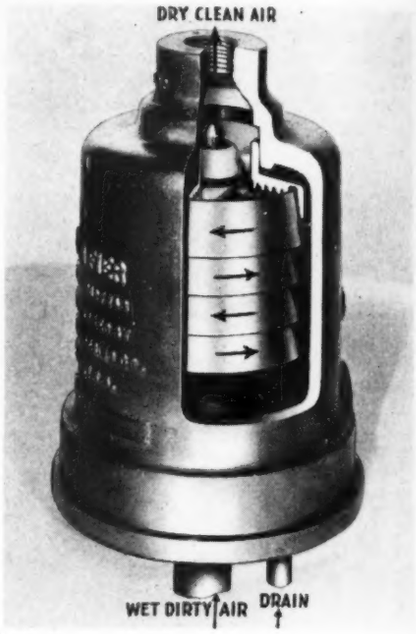
SILVER SEAL Aluminum Paint
An exceptionally durable, long lasting decorative coating. Ideal as an illuminative finish at danger points.

BLACK SEAL Anti-Rust Paint
An unusually tough and elastic finish. Waterproof, fume-proof, anti-corrosive and possessing extraordinary durability and resistance to dampness and other destructive elements.

Write us for Booklet W.

ASPHALT PRODUCTS CO., Inc.
Eastwood Station Syracuse, N. Y.

"Aridifiers" Product Clean Air and Gas



● The Logan Engineering Co., Chicago, Ill., announce that their line of Aridifiers for removing dust, moisture, oil, etc., from air and gas is now complete for all sizes of pipe lines from ⅜" to 10".

In passing through the unit foreign matter impinges on the multiplicity of revolving blades, propelled in opposite directions by the flow of air or gas. The arrested contamination and moisture is collected in the lower housing, from which it is drawn off as occasion warrants. The Aridifier operates with no other attention and creates no back pressure.

These units are designed for application to air lines to protect air operated equipment, porous diffuser plates or tubes; to gas lines to prevent accumulations of impurities in small orifices, needle valves, burners, etc.

The entire line of Logan Aridifiers are pictured and described in Bulletin 939, which gives complete operating and installation details.

For a copy write The Logan Engineering Co., 4912 Lawrence Ave., Chicago, Ill.

"Ranetite" For Transparent Waterproofing

● "Ranetite" No. V Clear Waterproof Coating is a material which combines aluminum and calcium stearates as the base. Being clear it is effectively employed on surfaces without changing the original texture or color. The improved "Ranetite" Coating consists of the regular transparent coating (boasting more than 25 years of successful history) to which the metallic stearate base is added. The coating neutralizes alkalines and is especially well suited for concrete work.

"Ranetite" No. V Clear Coating can be had in quantities from a single quart to 55-gal. steel drums. For more information, write "Ranetite" Mfg. Co., 1917 South Broadway, St. Louis, Mo.

IT'S RAINING

. . . so what!

Showers, drizzles, downpours — they're all alike to Tegul-MINERALEAD! Even floods don't bother this sulphur-base Ingot-form jointing compound. Water rolls right off those 10 lb. ingots ● Your men will find them easy to toss around and, when the melting pot needs a refill, just reach for the Ingot and the hammer. ● Joints heal quickly, so you can backfill and clear up. They'll be tight and tough, elastic to take more vibration, mechanical and thermal shock than they're likely ever to meet in service ● Since you can't "shake up" an ingot, you know **this** compound can't change composition en route ● You want **all** these advantages ● Write for complete information. The ATLAS MINERAL Products Company of Penna., Mertztown, Pennsylvania.

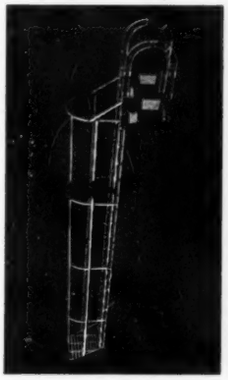
A Tegul PRODUCT

Tegul-

MINERALEAD

Aluminum Drop Ladder

A new all-aluminum overhanging ladder, for inspection, maintenance or repair work on tanks, standpipes, dams, bridges, buildings, boats, etc., has recently been developed by the Aluminum Ladder Co. of Tarentum, Pa.



This light-weight safety ladder is designed to hang from the top of the structure, and is held away from the wall so that workman can get a good foothold in climbing the rungs. An oval guardrail, 22" wide by 27" deep, descends from the top to the 22" by 24" platform at the bottom. Width of the ladder is 22 inches. What its height is, information from the manufacturer does not disclose.

Fabricated from aluminum, it weighs only 84 lbs. complete, and can readily be handled, yet it is strong enough to support three heavy men with perfect safety.

For complete specifications and prices, address Aluminum Ladder Co., 394 Adams St., Tarentum, Pa.

THE ENSLOW STABILITY INDICATOR

Provides Continuous Corrosivity Index

Base weighing 12 pounds can be removed, permitting wall mounting. Well constructed throughout. Art Metal Finish.

Write for Full Details

Phipps & Bird, Inc.

RICHMOND, VA.

"Flexo-Pac" Now Supplied by Eclat Rubber Company

● In previous issues of WATER WORKS & SEWERAGE have appeared items and articles concerning the invention of a "bugless" joint packing by Hayes R. Kuhns of Killbuck, Ohio. This packing, made of high grade rubber, is a sanitary substitute for pipe yarning materials so long used but now shown to harbor bacteria and in fact support bacterial growths. Such a situation harasses the water works man failing to deliver to the tap as fit water as that leaving his purification plant.

The original name chosen for this new sanitary all rubber yarning substitute was "Sani-Pac," which has now been changed to "Flexo-Pac" as announced by the manufacturer—The Eclat Rubber Co. of Akron, Ohio.

The Eclat announcement lists the several sizes and weights of the rubber jointing material for C. I. pipes of all sizes in the two types, "Wedge" and "Round", which are available in 150 to 200-ft. trial size coils, and quotes prices. Full directions for effective use of the cleanly and easy to use "rubber yarn" are given.

You've heard that old one about the pretty thing in a bathing suit and the man who "turned to 'rubber'"—well, Hayes Kuhns has an even better "yarn". So, if you would know more about this 'slick' jointing material, just drop a card to The Eclat Rubber Co., Akron, Ohio.

PATENTED

Quick Easy Lasting

TAPAX is the surest relief from rattling, banging manhole covers and offers you the simplest solution for noisy covers at a cost of comparatively a few cents an application. It will "stay put" for years. Ask for sample.

TAPAX MFG. CO., INC.

MAMARONECK NEW YORK

The Rustop System

of cathodic protection will be demonstrated at the National Convention in Booth No. 16.

We have much of interest to tell you that space won't permit.

On Page 117 of this issue is part of our story. You will find it interesting.

E. H. INGLE
General Manager

A. W. INGLE
Supt. of Instal.

will be present to answer questions.

ELECTRO RUST-PROOFING COMPANY

3d Nat'l Bldg., Dayton, Ohio

AUTOMATIC
Sewage Regulators

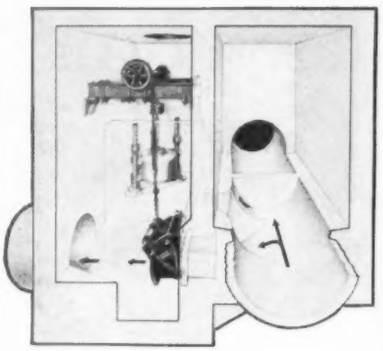


Fig. 54A.

Automatic Sewage Regulators are useful to control any hydraulic flow. Their principal use constitutes the automatic control of sewage. Control may be from "head" water (Type A) as shown by Fig. 54A, or from "tail" water (Type B). Under either type "A" or "B" the regulator gate may be arranged to cut off the flow entirely or partially as conditions of design require. By special means the regulator may be used as a governor to provide a fixed discharge regardless of head water conditions (Type C Control).

SEND FOR NEW BULLETINS

Various bulletins are available for free distribution. Bulletin No. 52 describes these equipments in a general way, giving useful information regarding normally standard construction details; Bulletin No. 53 describes the Type "C" control; Bulletin No. 54 outlines hydraulic problems usually encountered and contains suggestions and charts for their solution; Bulletin No. 55 is a mimeographed reproduction of a report of hydraulic tests made by Professor Horace Judd of Ohio State University; Bulletin No. 56 gives complete information regarding size and dimensions of structures required; Bulletin No. 57 describes a new type of diversion weir which reduces to a minimum the deposition of sludge in float compartments.

BROWN & BROWN, Inc.
LIMA, OHIO

Enslow Stability Indicator

● To meet a demand for a ready assembled Enslow Continuous Stability Indicator, the laboratory supply house of Phipps and Bird, Inc., Richmond, Va., have produced the unit here pictured.

This new piece of equipment has been designed in proportions suggested by the inventor and, after a period of in-service test, appears to be in all respects satisfactory.

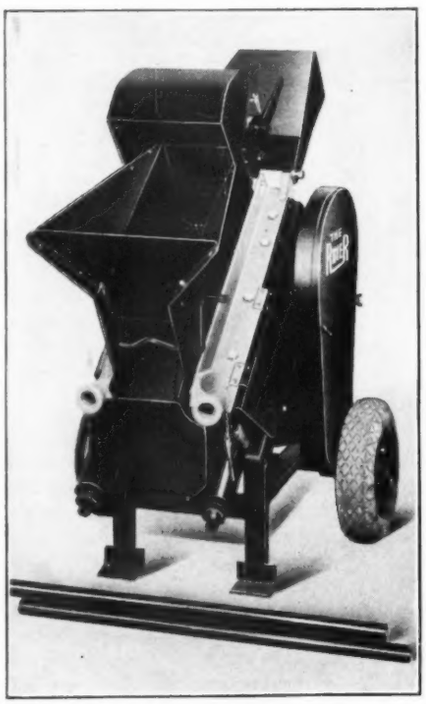
The apparatus consists of two contact tubes of 2 inch diameter connected in series through glass tubing. In service the primary tube is filled with finely ground marble, limestone, or chalk powder. The flow is upward. The secondary tube serves principally as a trap-tube. It is filled with marble or limestone chips, and the flow through it is also upward. The water is continuously run through the Indicator at a rate to insure two hours or longer contact with the calcium carbonate—a rapid dripping being a satisfactory rate.

The degree of corrosivity of the water is revealed by taking pH readings, and/or titrating for total alkalinity, of the water entering and leaving the apparatus—the greater the pH and alkalinity pick-up through the Indicator, the higher the corrosivity of the water. In connection with softening, the greater the drop in pH and total alkalinity the more scale forming is the water. The ideally balanced (stable) water is that which exhibits no change in either direction while in contact with calcium carbonate. Treatment of the water is regulated so as to produce a product with a "Stability Index" approximating zero. (It is to be noted that as the zero point is approached from either direction the Enslow Stability Index and that of Langelier, derived from mineral analysis and computations, becomes the same values.)

Phipps and Bird's reasonably priced "tailor-made" portable model of the Enslow Indicator is supported on a board 4⅝ inches wide and 48 inches high, finished in natural oak. Its non-tipping cast iron base weighing 12 pounds is 9½x10½ inches. The board can be easily removed from the base for attaching to the wall if desired. The base, however, makes the Indicator well adapted to portable or field use. The glass contact tubes are supported at top and bottom by heavy spun copper cups, making for ease in dismantling and re-assembling, if required. The small outlet glass tube runs through a nickle plated brass tube for support and protection.

With a high degree of satisfaction, in respect to simplicity of use and effectiveness, Enslow's Continuous Stability Indicator has been used in a number of plants, with the result that it has come to be considered by many operators as an almost indispensible piece of control equipment. In short, it provides the well known marble test for corrosivity, with assured accuracy, and at a marked saving in time and performance of laboratory technic. As the saying goes—"It Works While You Sleep".

For further details write Phipps and Bird, Inc., Cary Street at Ninth, Richmond, Va.



The 1940 Model Royer

Sludge Disintegrator Redesigned

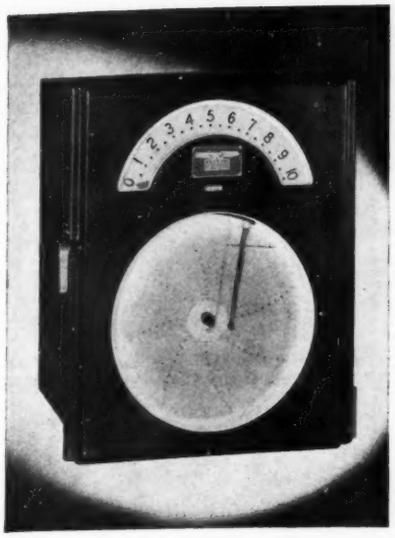
● The Royer Foundry & Machine Company have redesigned their Sewage Sludge Disintegrator for shredding, mixing, and otherwise putting sludge cake from drying beds in the best condition for use as a soil fertility builder.

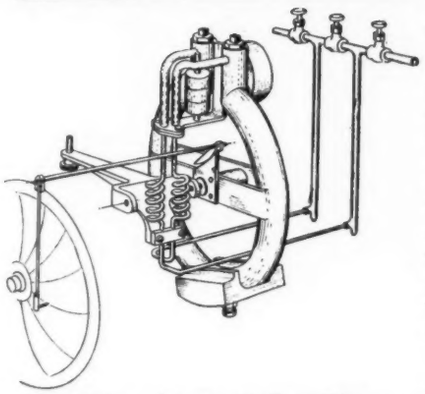
Redesigning the Disintegrator has effected reductions in weight up to 20% and lowered shoveling heights up to 7 inches. These changes affect electric powered models only, the gasoline models remaining unchanged.

The redesigned Model "NSB-2," (shown), has been reduced 120 lbs. in weight, to 465 lbs., and its shoveling height has been lowered by one-third of a foot. Capacities in every case remain unchanged and, of interest to prospective buyers, the redesign has also made possible lowered prices for the 1940 models.

For further details and prices, write The Royer Foundry and Machine Co., Kingston, Pa.

Novel Mechanical Ring-Balance Meter





The Meter with the Hollow Ring Mechanism

● A new mechanical meter of the ring-balance type for metering steam, water, gas, air, etc., has just been announced by Republic Flow Meters Co.

The unique feature of this meter is its hollow steel ring, or "horseshoe" which, with the toe end down, is vertically centered and balanced on a specially developed fulcrum, having ball bearings. In the U of the "toe" is the sealing fluid—mercury for high head differentials, oil for low differentials. Each side of the tubular "horseshoe" has a flexible top—connection from the tubes leading to the high and low pressure sides of the metering element—orifice, venturi tube, etc. The pressure differential thus causes the "horseshoe" to tip on its fulcrum toward the high head side, and in turn swing the rate of flow pointer and pen arm on the chart to the point where the tilting head is balanced by the movement of the calibrating weight at the top of the tube.

This new meter will give full scale readings on differentials as low as 3 in. of water, such being especially advantageous for low pressure gas and air measurement at water and sewage treatment plants. The meter is housed in a rugged steel case suitable for exposed locations, if required. It is easily adjusted by changing the calibrating weight, has a 12-in. evenly graduated chart, is furnished with any combination of indicator, recorder and cyclometer type integrator.

For Bul. 110 describing the new and interesting "Ring-Balance Flow Meter", write Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.

WITH THE MANUFACTURERS

Alan Drake Joins ALCO Products; Corrough Becomes General Manager

● Close on the heels of an announcement that Hugh M. Corrough has been made General Manager of the ALCO Products Division of American Locomotive Co. comes word that Alan Drake, one of this country's most capable and popular water works engineers, former Director of Water at Buffalo, has joined Mr. Corrough's staff as Sales Engineer.

Corrough

Drake

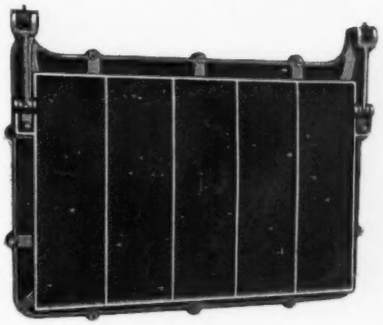
Mr. Drake has until just recently been connected with the construction project involving several miles of steel mains in Toledo's important water supply project. Here he handled a considerable quantity of Alco steel pipe, and in his new connection will sell the product which he has become so familiar with as purchaser and user.

Mr. Corrough has been connected with Alco Products since 1936. He has served as Chief Mechanical Engineer and more recently as Manager of Engineering.

Activated Alum Now Handling Filter Sand

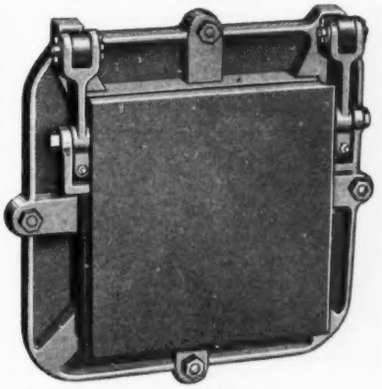
● Activated Alum Corporation of Baltimore, Md., has recently been appointed agents for the Cape May Filter Sand Company and will be in a position to recommend and supply the proper sand for filters. This is an addition to the effective Palmer filter cleaning "Filter Sweep" which Activated is now marketing and servicing, as announced in our March issue.

TIDE GATES



TYPE M-M.

Type M-M Tide Gates are extremely sensitive; are made of all metal construction; frames and shutters are normally made of cast iron; seating surfaces are accurately machined; hinges are of link type which hang from adjustable lugs; lug adjustment provides means to secure correct seating even though foot walls are slightly out of plumb. Type M-M gates are available for heads of 12', 20' and 40' head. Recommended especially for conditions of normally free discharge.



TYPE M-M-C

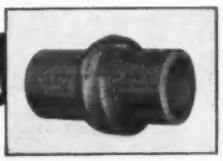
Type M-M-C Tide Gates are similar to Type M-M gates except that shutters are made cellular and designed to weigh slightly more than the displaced fluid. Recommended for conditions of normally submerged discharge.

TYPE M

Type M Tide Gates comprise circular designs. Also available in Type M-C which provides shutters of cellular construction.

Bulletins upon request.

BROWN & BROWN, Inc.
LIMA, OHIO



GASKET AND FORM

The Perfected Method for Making SEWER PIPE JOINTS OF CEMENT

- No jute used—gasket centers spigot.
- Definite space in each joint for cement.
- Form confines cement-grout to lower portion of joint.
- Particularly advantageous in water-bearing trenches.
- Infiltration minimized.

L. A. WESTON **Adams, Mass.**

Prevent wear and cutting of rods, plungers, shafts and valve stems by using

MABBS RAWHIDE PACKING

In Your Water Works and Sewage Plants

IT LASTS LONGER — *Is Anti-Frictional, Saves Power, Labor and Repairs. Will prove the cheapest packing that can be bought.*

Trade Mark Reg. U. S. Pat. Off.

Mabbs Hydraulic Packing Co.

Incorporated 1892

431 S. Dearborn St., Chicago, U. S. A.

ARROWHEAD Grating and Treads

Engineers' Handbook sent on request

ARROWHEAD IRON WORKS

431 W. 5th Street

Kansas City, Mo.

EDSON'S NEW HAND PUMP

Smallest Diaphragm Pump Made, 2" Suction Open Discharge. Capacity 1400 G.P.H. Weight 50 lbs.

THE EDSON CORP'N
49 "D" Street
So. Boston, Mass.

NEW YORK: 142 Ashland Pl., Brooklyn

CHICAGO: 1061 Peoples Gas Building

Catalog "T" Gives Full Data, Also Edson Hand and Power Pumps, Suction Hose and Pump Accessories

Merle Lofton Now Mfgrs. Representative

● Merle E. Lofton, born and reared in the water works business, and former Sales Manager of the Columbia Valve and Hydrant Co. of Chattanooga (now a Division of Mueller Co.), and more recently connected with The Grinnell Company, has gone into business for himself.

He is establishing an office in Atlanta and will represent manufacturers of water works and sewerage equipment and materials in the South, where he has a host of acquaintances and friends. Any manufacturer desirous of securing effective representation in the South and Southeast would do well to address Mr. Lofton at 750 Brookside Drive, Atlanta, Ga.

Applebaum New Permutit Director

● S. B. Applebaum, Vice-President and Secretary of The Permutit Co., manufacturers of water conditioning equipment, was elected a Director at the company's recent annual meeting.

Mr. Applebaum has been with The Permutit Company for more than 25 years, and was Technical Manager before becoming Vice-President. His contributions in the development of water conditioning processes have been noteworthy. He has long been an active member of the American Water Works Association, and a frequent contributor of technical papers and articles.

W & T's Hockett Says, "Go South Young Man!"

W. A. Hockett, Wallace & Tiernan's export manager, who has just returned from an extended business trip through Central and Northern South America, says that from observations in Nicaragua, Costa Rica, Panama, Colombia and Venezuela it is apparent that travel (both pleasure and business) between the United States and those countries has been much heavier than usual at this time of year.

Of the countries Mr. Hockett visited, he considers Venezuela the most interesting to the student of economics and to exporters. This nation is unique in that it has no internal or external debt, is still firmly on the gold standard and has practically no unemployment problem. This condition makes it favorable for the importation of machines and products from the United States. Business in general is booming in this prosperous country.

Mr. Hockett, in commenting to us, said: "Certainly more North Americans should 'discover' their sister Republics to the south, —not only because of their commercial possibilities but also because they offer those things most eagerly sought by the traveling public—welcome change of climate, beautiful and often magnificent scenery, and excellent traveling facilities.

Sewage Gas, Gasoline, Butane and Diesel engines.

●

Generator sets for standby or continuous duty service.

●

Gasoline engines to meet Fire Underwriters' requirements.

Lawrence Stahl & Co., Inc.

21 Morris Street, New York, N. Y.

"VICTOR"

Filter Cloths — All Kinds

Woven specially for rotary vacuum filters

Cotton and Wool Filter Cloths

Filter Flannels for ALL Purposes

"ACIDPROOF" Cloths woven from plastic resins

WM. W. STANLEY CO., Inc.

401 BROADWAY, N. Y. C.

FOR DITCHING JOBS

If you have a ditching job, this P&H Multi-Service Crawler Hoist for backfilling and pipe handling is a real bargain. Triple drum arrangement gives it unusual flexibility. Maneuvers smoothly. Send for Bulletin X-39.

Address Box No. 40,
Water Works and Sewerage
330 South Wells St., Chicago, Ill.

Position Open

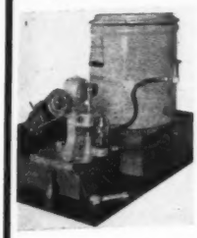
Sanitary Engineer or Chemist—A young man with one or two years' experience in a sewage plant laboratory to fill position of Plant Chemist. Salary available $1600 (possibly 1800) per year, but opportunity for advancement to position of Plant Superintendent is excellent for the right man. Location in a Northeastern State. Address "Opportunity" % Water Works & Sewerage, 155 E. 44th St., New York, N. Y.

Position Wanted

Chemical Engineer who has specialized in industrial filtration for over 20 years. Wide experience in research, sales, installation and operation. Many processes in the industries improved where the separation of solids from liquids meant success or failure. Address Box 42, Water Works & Sewerage, 330 So. Wells St., Chicago, Ill.

Water Works Engineer; Member A.S.C.E.; registered in Penna. and West Virginia; over 25 years experience on design of water works and hydraulic structures and constructing of all types of water works structures and including considerable sewerage disposal design and construction. Extensive valuation experience with utilities and Public Service Commission. Now available; any capacity; any location. Address W. H. C., Water Works & Sewerage, 330 S. Wells St., Chicago, Ill.

WILSON CHEMICAL FEEDER



Outstanding features are quick feed adjustment, visible valves, flexible cylinders; feeds against 150-lb. pressure, and proof against corrosive chemicals.

Motor driven, positive displacement, pump type feeder. It is illustrated as a constant rate feeder though also furnished as Type MD-H with fluid meter control, and when so arranged is a measure-to-measure proportioning feeder.

This is a sturdy dependable heavy duty feeder.

Write for Bulletin

Wilson Chemical Feeders, Inc.
BUFFALO, NEW YORK

(PHIPPS & BIRD)

LABORATORY EQUIPMENT

Such as . . .

- *pH ELECTROMETERS*
- *Drying Ovens*
- *Glassware, Chemicals, and Equipment for Laboratory tests.*

Also . . . SOLUTION FEEDERS for feeding corrosive solutions in high concentrations, BALDWIN ALUMINA OUTFIT for determining total alumina in filtered water.

Write for Descriptive Literature

PHIPPS & BIRD, Inc.
915 East Cary Street RICHMOND, VA.

Complete equipment for Filtration Softening and all other kinds of

Water Purification **PLANTS**

Dry Chemical Feeders—Swimming Pool Filters

Consult us any time—no obligations.

E. W. BACHARACH & CO.
Rialto Bldg., Kansas City, Mo.

The Meter-Master

RATE RECORDER FOR WATER METERS

Send For Literature

F. S. BRAINARD & CO.
246 Palm Street, Hartford, Conn.

Penn Salt Establishes Market Research Dept. R. L. Davies, Manager

● The Pennsylvania Salt Mfg. Co. has recently established a Market Research Department.

The functions of this new department is that of making studies of existing markets for products now manufactured by the company, and those under development. It will also be responsible for launching the sale of new products as they appear, and will suggest new products. With all of the above as a basis, sales policies will be more effectively formulated.

The Market Research Dept. is being headed by Richard L. Davies, well known in the Chemical Field.

P. S. Wilson Representing "Rusta-Restor"

● P. S. Wilson, who recently resigned as Technical Assistant to the Secretary of A.W.W.A. in order to resume his practice as Water Works Consultant which he left to serve A.W.W.A. during the period of reorganization, is now agent for the "RUSTA-RESTOR" method of providing cathodic protection for pipe lines, iron and steel water tanks and submerged metal equipment in general.

In this recent endeavor, Mr. Wilson has become connected with The Gregg Co., 1418 Walnut St., Philadelphia, who are representatives of "Rusta-Restor" Corp. in Eastern New York, New Jersey, Eastern Pennsylvania, Delaware and Northern Maryland. Mr. Wilson's office is at 326 Washington St., Glen Ridge, N. J.

D. S. Kerr Made Manager of Allis-Chalmers' Atlanta Office

● D. S. Kerr, for the past 10 years Manager of Allis-Chalmers' Chattanooga office, has recently been appointed Manager of the Atlanta office. The Chattanooga and Knoxville offices will also be under his jurisdiction. Mr. Kerr is a Purdue graduate and has been with the Allis-Chalmers Company since 1922.

Cooper-Bessemer Opens Sales Office in St. Louis W. S. Arthur, Manager

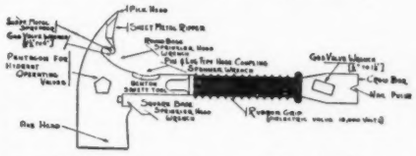
● Cooper-Bessemer Corporation of Mt. Vernon, Ohio, manufacturers of gas and Diesel engines and compressor units, have just established a Sales Office in St. Louis, Mo., to serve most of Missouri, Southern Illinois and parts of Arkansas and Mississippi.

W. S. Arthur, who has been made St. Louis Manager, has a fine background of experience in production and sales of pumps and engines. He at various times has been connected with Foos Engine Co., Worthington, and Superior Engine Co. The last named, Mr. Arthur was serving as manager of their Chicago offices before accepting the new position.

Cooper-Bessemer's St. Louis office is located in the centrally located Arcade Bldg.

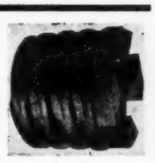
Benton Safety Tool

A TOOL OF 101 USES +



● With the above illustrations very little need be stated in words to convince one of the more than 101 Uses to which such an instrument can be put.

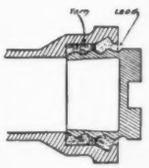
BENTON TOOL CORPORATION
426 Engineers Bldg.
CLEVELAND, OHIO



REMOVABLE SCREW PLUGS

Save Money, Time & Tools

Thousands in use by hundreds of cities in the United States and its possessions for over 32 years.



WHY break and destroy plug when removing? take a chance of breaking fittings? break up your chisels and cleavers? have the water off so long, causing consumers inconvenience? increase your fire risk when it can be avoided by using—

RAPP REMOVABLE SCREW PLUGS
— The Cheap and Easy Way —

W. M. RAPP
P.O. Box 584, Atlanta, Georgia, U. S. A.

CAST IRON PIPE

The Standard Material

for

Underground Mains

THE CAST IRON PIPE RESEARCH ASSOCIATION

Thomas F. Wolfe, Research Engineer
1015 Peoples Gas Bldg. Chicago, Ill.

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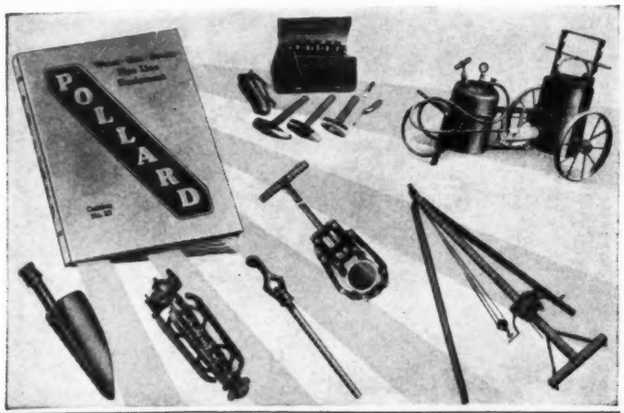

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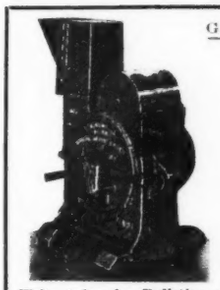

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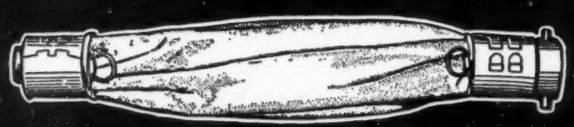

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FOREWORD

The Publisher presents herewith the 1940 Reference and Data Number of WATER WORKS AND SEWERAGE.

This section, prepared by Linn H. Enslow, Editor, gives the equivalent of a handbook of data for designing engineers, managers and operators of water works and sewerage systems.

The contents represent matter carefully selected from the files of WATER WORKS AND SEWERAGE and other sources named in the text. In addition, a considerable effort has been made to secure the latest hydraulic tables and standards, and to present the most economical and modern methods.

Even though supplied at no charge to subscribers beyond the regular subscription fee, the same conscientious work has been put into the preparation of this Data Section as would be expected in a book devoted exclusively to the same type of material, and published separately.

NOTE

All *new* subscribers may have a copy of this special issue, so long as the supply lasts, and at no extra cost.

Old subscribers will note that considerable material in this issue has appeared in earlier issues. The nature of material repeated is such that we find it difficult to replace. With the constant influx of new subscribers in mind, the more basic material is permanently retained, some is repeated in alternate years, some is permanently dropped.

Our endeavor is to repeat not more than 50% of the material which has appeared the year previous.—Editor.

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CLASSIFIED INDEX of PRODUCTS

Although this index is not published as a COMPLETE index of all materials and equipment used in the Water Works and Sewerage fields—it really is a very comprehensive list of products. It includes equipment and materials produced or marketed in this field by 172 manufacturers who have used WATER WORKS AND SEWERAGE in advertising such products during 1939 and 1940. Of these 172 manufacturers you will find the advertisements of 147 in this issue.

ABRASIVES
Carborundum Co., Niagara Falls, N. Y.

ACID, SULPHURIC AND HYDROCHLORIC
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Ozark Chemical Co., Tulsa, Okla.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ACTIVATED AND BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ACTIVATED CARBON
Cliffs-Dow Chemical Co., Marquette, Mich.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Darco Corporation, 60 E. 42nd St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Industrial Chemical Sales Division, West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
L. A. Salomon & Bro., 216 Pearl St., New York City.

ACTIVATED SLUDGE EQUIPMENT
Carborundum Co., Niagara Falls, N. Y.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Vogt Mfg. Co., Louisville, Ky.

AERATION APPARATUS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

AGITATORS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., Inc., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Vogt Mfg. Co., Louisville, Ky.

AIR BLOWERS
(See Blowers, Air)

AIR COMPRESSORS
(See Compressors, Air)

AIR VALVES
(See Valves, Air)

ALLOY CAST IRON PIPE AND FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

ALTERNATORS, ELECTRIC
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, O.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.

ALUM, AMMONIA
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

ALUM, BLACK
Activated Alum Corp., Curtis Bay, Baltimore, Md.

ALUM (FILTER), COMMERCIAL, IRON-FREE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Faesy & Besthoff, Inc., 22 E. 40th St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIA, ANHYDROUS & AQUA
The Barrett Co., 40 Rector St., New York City, N. Y.
Dow Chemical Co., Midland, Mich.
General Chemical Co., 40 Rector St., New York City.
Great Western Div., Dow Chem. Co., Pittsburg, Cal.
Mathieson Alkali Wks., Inc., 60 E. 42nd St., New York City
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

AMMONIATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engrg. Co., 3915 29th St., Long Island City, N. Y.
Proportioneers, Inc., 9 Codding St., Providence, R. I. (Aqua)
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

ANALYTICAL WARE
Carborundum Co., Niagara Falls, N. Y.
Phipps & Bird, Inc., Richmond, Va.

AQUA AMMONIATORS
(See Ammoniators)

ASBESTOS-CEMENT PIPE
Asbestos-Cement Pipes, Inc., 225 Broadway, New York City.
Johns-Manville Co., 22 E. 40th St., New York City.

ASH AND COAL HANDLING MACHINERY
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Rheolaveur Co., Pittsburgh, Pa.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

AUTOMATIC FILTER AND SOFTENER CONTROLS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.

Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., Philadelphia, Pa.

BACK FILLERS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.

BAR SCREENS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

BASE-EXCHANGE SILICATE
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.

BEARINGS, ROLLER & BALL
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 519 N. Holmes Ave., Indianapolis, Ind.

BINS, STORAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa

BITUMINOUS COATINGS AND LININGS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

BLACK ALUM
Activated Alum Corp., Curtis Bay, Baltimore, Md.

BLEACHING POWDER
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

BLOWERS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Roots-Connersville Blower Corp., Connersville, Ind.

BLOWERS (GASOLINE) ENGINE DRIVEN, PORTABLE)
Homelite Corporation, Port Chester, N. Y.

BOILER BLOWOFF APPARATUS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.

BOILER FEED PUMP CONTROL
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

BOILER FEEDWATER TREATMENT
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Buromin Co., 300 Ross St., Pittsburgh, Pa.
Chain Belt Co., Milwaukee, Wis
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hall Laboratories, Inc., 300 Ross St., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Penn.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

BOILER FURNACE, BRICK
Carborundum Co., Niagara Falls, N. Y.

BOILER PLANT ACCESSORIES
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

BOILERS, GAS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

BOILER WATER PURIFICATION APPARATUS
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Chain Belt Co., Milwaukee, Wis.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Dorr Co., 570 Lexington Ave., New York City.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 301 W. Pershing Rd., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

BOXES, VALVES AND METERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

BRAKES, MAGNETIC, MECHANICAL, HYDRAULIC
The Clark Controller Co., 1146 East 152nd St., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

BRASS GOODS
(See also Pipe, Brass.)
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Mueller Co., Decatur, Ill.

BREECHINGS, STEEL
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

BUCKETS, SEWER
Champion Corp., Hammond, Ind.
Elmco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

BUFFER SOLUTIONS & MIXTURES
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

CALCIUM HYPOCHLORITE
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CALKING MACHINES & TOOLS
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

CARBON-ACTIVATED
(See Activated Carbon.)

CARBONATORS (Recarbonation).
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

CAR SPOTTERS & HAULAGE SYSTEMS
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.

CASTINGS, IRON, STEEL, ALLOY STEEL, ETC.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Chain Belt Co., Milwaukee, Wis.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill. (Bronze).
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
M & H Valve & Fittings Co., Anniston, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

CAST IRON PIPE
(See Pipe.)

CATCH BASIN INLET
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

CATCH BASINS, CORRUGATED IRON
Armco Drainage Products Assn., Middletown, Ohio.

CATHODIC PROTECTIVE PROCESS
Electro Rust-Proofing Co., Third Natl. Bldg., Dayton, Ohio.

CAUSTIC SODA
The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa
Dow Chemical Co., Midland, Mich
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

CEMENT
Portland Cement Assn., 33 W Grand Ave., Chicago, Ill.

CEMENT, ASBESTOS PIPE
Johns-Manville, 22 E. 40th St., New York City.

CEMENT PIPE
(See Pipe, Cement: Pipe, Concrete.)

CEMENT LINED PIPE
(See Pipe.)

CEMENTS, ACID PROOF
Atlas Mineral Prod. Co., Mertztown, Pa.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.

CEMENTS, REFRACTORY
Carborundum Co., Perth Amboy, N. J.
Johns-Manville, 22 E. 40th St., New York City.

CEMENTS, SEWER PIPE
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

CEMENTS, WATER MAINS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Girard Trust Bldg., Philadelphia, Pa.

CHAINS (Elevating, Conveying & Power Transmission)
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

CHEMICAL CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., Homer City, Pa.

CHEMICAL FEEDING & PROPORTIONING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Calgon, Inc., 300 Ross St., Pittsburgh, Pa.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Syntron Co., Homer City, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeder, Inc., 110 Washington St., Buffalo, N. Y.

CHEMICALS FOR WATER PURIFICATION
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
The Columbia Alkali Corp., Barberton, Ohio.
Darco Corp., 60 E. 42nd St., New York City.
Diamond Alkali Co., Pittsburgh, Pa.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York.
Innis-Speiden & Co., 117 Liberty St., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Mathieson Alkali Works, Inc., 60 E. 42nd St., New York.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Solvay Sales Corp., 40 Rector St., New York.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

CHEMISTS AND ENGINEERS
(See Directory of Experts, pages 116, 117.)

CHLORIDE, FERRIC
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Div., Dow Chemical Co., Pittsburg, Cal.

Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORIDE OF LIME (CHLORINATED LIME)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

CHLORINATORS
(See also Hypochlorinators.)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Pardee Engrg. Co., 3915 29th St., Long Island City, N. Y.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan, Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

CHLORINE, LIQUID
The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Great Western Div., Dow Chem. Co., Pittsburg, Cal.
Mathieson Alkali Wks., 60 E. 42nd St., New York City.
Monsanto Chem. Co., St. Louis, Mo.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York.
Wallace & Tiernan, Inc., Newark, N. J.

CHLORINE CONTROL EQUIPMENT
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

CHUTES, COAL, ETC.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Link Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

CLAMPS AND SLEEVES, PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

CLAMPS, BELL JOINT
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CLAMPS, PIPE REPAIR
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CLARIFIERS, SEWERAGE AND WATER
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.

CLEANING SEWER MAINS
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N. Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

CLEANING WATER MAINS
National Water Main Cleaning Co., 50 Church St., New York City.

COAGULANTS & COAGULATION CONTROL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich.
Innis-Speiden & Co., 117 Liberty St., New York City.
Monsanto Chem. Co., Merrimac Div., Everett Station, Boston, Mass.
Monsanto Chemical Co., St. Louis, Mo.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Wallace & Tiernan Co., Newark, N. J.

COAL & ASHES HANDLING MACHINERY
(See Ash & Coal Handling Machy.)

COATINGS, ACID & ALKALI-PROOF FOR CONCRETE, STEEL AND WOOD
Asphalt Products Co., Inc., Syracuse, N. Y.
Atlas Mineral Products Co., Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Philadelphia Quartz Co., Philadelphia, Pa.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

COATINGS AND LININGS
(See Bituminous Coatings and Linings.)

COCKS, CURB, METER, CORPORATION, ETC.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COLLECTORS (SLUDGE)
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.

COMBUSTION INDICATORS AND RECORDERS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
Permutit Co., 330 W. 42nd St., New York City.

COMMINUTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

COMPARATORS (COLOR)
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

COMPOUNDS, SEWER JOINT
Atlas Mineral Prod., Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.

COMPRESSORS, AIR
De Laval Steam Turbine Co., Trenton, N. J.
Fuller Co., Catasauqua, Pa.
Gardner-Denver Co., Quincy, Ill.

CONCRETE—ARCHITECTURAL DESIGN
Roberts & Schaefer Co., 307 N. Michigan Ave., Chicago, Ill.

CONCRETE COLORING COMPOUNDS
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.

CONCRETE HARDENER
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Philadelphia Quartz Co., Philadelphia, Pa.
Standard Silicate Div., Diamond Alkali Co., Pittsburgh, Pa.

CONCRETE MIXERS
Chain Belt Co., Milwaukee, Wis.

CONCRETE PIPE FORMS
Quinn Wire & Iron Works, Boone, Iowa.

CONCRETE PIPE
(See Pipe, Concrete.)

CONCRETE Z-D ROOFS
Roberts & Schaefer Co., 307 N. Michigan Ave., Chicago, Ill.

CONDENSERS (STEAM)
Amer. Cast Iron Pipe Co., Birmingham, Ala.
U. S. Pipe & Foundry Co., Burlington, N. J.
Worthington Pump & Machy. Corp., Harrison, N. J.

CONTROLLERS, AUTOMATIC, ELECTRIC
Bender Warrick Corp., 128 Pierce St., Birmingham, Mich.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Level Controls Co., 833 Hampden Ave., St. Paul, Minn.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

CONTROLLERS, FLOW, LEVEL, PRESSURE, RATIO, TEMPERATURE
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Hagan Corp., 300 Ross St., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York, N. Y.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Water Level Controls Co., 833 Hampden Ave., St. Paul, Minn.

CONVEYORS AND CONVEYING EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dracco Corp., Cleveland, Ohio.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Fuller Co., Catasauqua, Pa.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Mfg. Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., Homer City, Pa.

COOLING TOWERS
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.

COPPER, BRASS, BRONZE
American Brass Co., Waterbury, Conn.
Mueller Brass Co., Port Huron, Mich.

COPPERAS
Innis-Speiden & Co., 117 Liberty St., New York City.
Pennsylvania Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

COPPER SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis-Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Tennessee Corp., 621 Grant Bldg., Atlanta, Ga.

COPPER TUBE, FLEXIBLE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

COUPLINGS & CONNECTIONS, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

COUPLINGS, FLEXIBLE
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Bartlett Hayward Div., Baltimore, Md.
Link Belt Co., 220 S. Belmont Ave., Indianapolis, Ind.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

CRANES & HOISTS
Link-Belt Speeder Corp., 301 W. Pershing Rd., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

CULVERTS
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City (Asbestos-Cement).
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J. (Cast Iron)
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

CURB BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., Cleveland, Ohio.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

DECHLORINATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIAPHRAGM, PUMP
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

DIFFUSERS—PLATES & TUBES
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DIGESTERS EQUIPMENT (SLUDGE)
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DISTRIBUTORS (FILTER)
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

DRAINS, STORM
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

DRIVES, CHAIN
Chain Belt Co., Milwaukee, Wis.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

DRY CHEMICAL FEEDERS
(See Chemical Feeding Equipment)

DRYERS, ROTARY
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

ELECTRICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.

ELEVATING AND CONVEYING EQUIPMENT
(See Conveyors & Conveying Equipment.)

ENGINEERS AND CHEMISTS
(See Directory of Experts, pages 116, 117.)

ENGINES, DIESEL
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Rathbun-Jones Engrg. Co., Toledo, Ohio.
Lawrence Stahl & Co., Inc., 21 West St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

ENGINES, SEWAGE SLUDGE GAS
Rathbun-Jones Engrg. Co., Toledo, Ohio.
Lawrence Stahl & Co., Inc., 21 West St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

EXPANSION JOINTS—PIPE
(See Joints—Expansion, Pipe)

FEED, CHEMICAL
(See Chemical Feeding Equipment.)

FEED WATER FILTERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

FEED WATER HEATERS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Permutit Co., 330 W. 42nd St., New York City.
Worthington Pump & Machy. Corp., Harrison, N. J.

FEED WATER TREATMENT
(See Boiler Feed Water Treatment)

FERRIC CHLORIDE, LIQUID & ANHYDROUS
Diamond Alkali Co., Pittsburgh, Pa.
Dow Chemical Co., Midland, Mich. (Liquid & 60% crystal)
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
General Chemical Co., 40 Rector St., New York City.
Great Western Div., Dow Chem. Co., Pittsburg, Cal.
Innis, Speiden & Co., 117 Liberty St., New York City.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa. (Liquid)

FERRIC CHLORIDE FEEDERS
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Omega Machine Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.

FERRIC SULFATE
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Monsanto Chem. Co., St. Louis, Mo.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Tennessee Corp., 621 Grant Bldg Atlanta, Ga., & Lockland, O.

FERROUS SULPHATE
General Chemical Co., 40 Rector St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.

FILTER-AIDS
Johns-Manville, 22 E. 40th St., New York City. (Celite.)
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER CLEANING PROCESS
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., 230 Park Ave., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER CLOTHS
(Cotton, Wool & Jute)
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTER FABRICS, ACID-PROOF
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

FILTERING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Filtration Equipment Co., 10 E. 40th St., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Underpinning & Foundation Co., Inc., 155 E. 44th St., New York City (For Sewage)

FILTER PLATES AND TUBES
Carborundum Co., Niagara Falls, N. Y.

FILTER RATE CONTROLLERS & GAGES
(See Rate Controllers.)

FILTER & WATER SOFTENING PLANTS (COMPLETE)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Neville Island P. O., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.

FILTERS—MAGNETITE
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Filtration Equipment Corp., 10 E. 40th St., New York City.

FILTERS, VACUUM
Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.

FILTER UNDERDRAINS (PIPE & PLATES)
American Water Softener Co., Lehigh & 4th Sts., Philadelphia, Pa.
Armco Drainage Products Assn., Middletown, Ohio.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FILTER WASH CONTROL
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FILTER SAND
Activated Alum Corp., Curtis Bay, Baltimore, Md.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 59 E. Van Buren St., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

FITTINGS, PIPE, SOLDER TYPE
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Port Huron, Mich.

FITTINGS, TEES, ELLS, ETC.
American Brass Co., Waterbury, Conn.
American Cast Iron Pipe Co., Birmingham, Ala.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., Cleveland, Ohio.
M & H Valve Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

FLASH MIXING EQUIPMENT
Ralph B. Carter Co., 53 Park Pl., New York City.
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Chain Belt Co., Milwaukee, Wis.
Carborundum Co., Niagara Falls, N. Y.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

FLEXIBLE JOINTS
(See Joints, Flexible Pipe.)

FLOATING COVERS
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

FLOATLESS CONTROLS
(All Electric)
Bender Warrick Corp., 128 Pierce St., Birmingham, Mich.

FLOCCULATING EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Carborundum Co., Niagara Falls, N. Y.
Ralph B. Carter Co., 53 Park Pl., New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

FLOOR GRATING
Arrowhead Iron Wks., 421 W. 5th St., Kansas City, Mo.

FLOOR STANDS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa (Motor & Electrically Operated)
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

FLOW METERS
Northrop & Co., Inc., 50 Church St., New York City.

FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

FLOW REGULATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

FLUMES, IRON & STEEL
Armco Drainage Products Assn., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

FOOT VALVE WITH STRAINER
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., So. Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood, Philadelphia, Pa.

FORMS & GASKETS FOR PIPE JOINTS
Johns-Manville, 22 E. 40th St., New York City.
L. A. Weston, Adams, Mass.

FURNACES, MELTING, POURING LADLES, POTS, ETC.
Atlas Mineral Products, Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GARBAGE DISPOSAL APPARATUS
Carborundum Co., Perth Amboy, N. J.
Chain Belt Co., Milwaukee, Wis.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

Underpinning & Foundation Co., 155 E. 44th St., New York City.

GAS DIFFUSERS
Carborundum Co., Niagara Falls, N. Y.
Dorr Co., 570 Lexington Ave., New York City.
Vogt Mfg. Co., Louisville, Ky.

GAS HOLDERS
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

GAS PUMPS
(See Pumps, Gas)

GAS PURIFICATION
(Equipment & Materials)
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Koppers Co., Pittsburgh, Pa.

GAS REGULATORS
(Pressure & Flow)
(See Regulators—Water & Gas)

GATES, SHEAR
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.

GATES, SLUICE
Armco Drainage Products Assn., Middletown, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.

GATES, TIDE
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.

GATE VALVE HOUSING
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.

GATE VALVES
(See Valves, Gate.)

GAUGES (Liquid Level, Pressure Recording)
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City (Pressure)
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.
Wallace & Tiernan Co., Inc., Newark, N. J.

GEARS, SPEED REDUCING
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GENERATORS, SETS, ELECTRIC & DIESEL ENGINES
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y. (Gasoline Engine Driven and Portable.)
Northrop & Co., Inc., 50 Church St., New York City (Gasoline Driven Portable)
Lawrence Stahl & Co., Inc., 21 West St., New York City. (Also Standby and Gasoline)
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump & Machy. Corp., Harrison, N. J.

GOOSENECKS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Co., Decatur, Ill.

GRATINGS, FLOORINGS
Arrowhead Iron Wks., Kansas City, Mo.

GREEN SAND (Zeolite)
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

GRINDERS
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.

GRIT CHAMBER EQUIPMENT
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

HOSE COUPLING WRENCH
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

HOSE, STEAM, AIR, WATER, SUCTION
American Brass Co., Waterbury, Conn.
Edson Corp., 49 D St., So. Boston, Mass.
Northrop & Co., Inc., 50 Church St., New York City.

HYDRANT OPERATING VALVE WRENCH
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

HYDRANT PUMPS
(See Pumps, Hydrant.)

HYDRANTS (FIRE)
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Decatur, Ill.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

HYDRAULICALLY OPERATED GATE VALVES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

HYDROGEN ION EQUIPMENT
Permutit Co., 330 W. 42nd St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

HYPO-CHLORINATORS
E. W. Bachrach & Co., Rialto Bldg., Kansas City, Mo.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Pardee Engrg. Co., 3915 29th St., Long Island City, N. Y.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

HYPOCHLORITES (High Test)
(See Calcium Hypochlorite)

INCINERATORS
Dorr Co., Inc., 570 Lexington Ave., New York City.
Koppers Co., Engrg. & Constr. Div., Pittsburgh, Pa.
Nichols Engr. & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

INDICATOR POSTS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Iowa.
Ludlow Valve Mfg. Co., Troy, N. Y.
M & H Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
R. D. Wood Co., Philadelphia, Pa.

INDICATORS, LARGE DIAL, ILLUMINATED
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

INSULATION
Carborundum Co., Perth Amboy, N. J.
Ford Meter Box Co., Wabash, Ind. (Water Meter).
Johns-Manville, 22 E. 40th St., New York City.

IRON SULPHATE
Innis, Speiden & Co., 117 Liberty St., New York City.

JOINTING COMPOUND
Atlas Mineral Prod. Co., Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Mueller Co., Decatur, Ill.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.

JOINTS, EXPANSION—PIPE
Amer. Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, FILLER
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.

JOINTS, FLEXIBLE PIPE
American Cast Iron Pipe Co., Birmingham, Ala.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Lock Joint Pipe Co., Ampere, N. J.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

JOINTS, MECHANICAL (FLEXIBLE)
American Cast Iron Pipe Co., Birmingham, Ala.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Servicised Products Corp., 6051 W 65th St., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
Weston's Gaskets & Forms, Adams, Mass.
R. D. Wood Co., Philadelphia, Pa.

JUTE, BRAIDED AND TWISTED
Atlas Mineral Prod. Co., Mertztown, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Johns-Manville, 22 E. 40th St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

LABORATORY APPARATUS
Carborundum Co., Niagara Falls, N. Y.
Corning Glass Works, Corning, N. Y.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Wallace & Tiernan, Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

LEAK LOCATING INSTRUMENTS
(See Water Leak Locating Instruments)

LIQUID CHLORINE
(See Chlorine, Liquid.)

MANHOLE CUSHIONS (anti-Rattle)
Tapax Mfg. Co., Mamaroneck, N. Y.

MANOMETERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METER ACCESSORIES, BOXES, HOUSING, ETC.
Badger Meter Co., Milwaukee, Wis.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METER COUPLINGS & YOKES
Badger Meter Mfg. Co., Milwaukee, Wisc.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
Neptune Meter Co., 50 West 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, GAS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, O.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Roots-Connersville Blower Corp., Connersville, Ind.

METERS, PITOT
Pitometer Co., 50 Church St., New York City.
Simplex Valve & Meter Co., 68th & Upham Sts., Philadelphia, Pa.

METER TESTING EQUIPMENT
Badger Meter Mfg. Co., Milwaukee, Wis.
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

METERS, VENTURI
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

METERS, WATER & SEWAGE
Badger Meter Mfg. Co., Milwaukee, Wis.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron & Foundry Co., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
National Meter Co., 4259 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Phoenix Meter Corp., Prince Bay, Staten Island, New York.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.

METER WASHERS
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

MIXERS, CHEMICAL
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Roberts Filter Mfg. Co., Darby, Pa.
Vogt Mfg. Co., Louisville, Ky.
Wallace & Tiernan Co., Inc., Newark, N. J.

MIXERS, CONCRETE
(See Concrete Mixers)

MIXING EQUIPMENT
(Water & Sewage)
Ralph B. Carter Co., 53 Park Place, New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.

MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

MOTORS, ELECTRIC
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

NIPPLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

NOZZLES, FLOW
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Chain Belt Co., Milwaukee, Wis.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

NOZZLES, SPRAY
Chain Belt Co., Milwaukee, Wis.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa
Mueller Brass Co., Port Huron, Mich.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

ODOR CONTROL
Cloroben Corp., 90 Forrest St., Jersey City, N. J.

ODOR & CARBON EVALUATION AIDS
Darco Corp., 60 E. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
L. A. Salomon & Bro., 216 Pearl St., New York City.

OPERATING TABLES
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

ORIFICES
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

PACKING
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.

PACKING, RAWHIDE
Mabbs Hydraulic Packing Co., 431 S. Dearborn St., Chicago, Ill.

PAINT, ACID RESISTING
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Asphalt Products Co., Inc., Syracuse, N. Y.
Atlas Mineral Prod. Co., Mertztown, Pa.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PAINTS, TECHNICAL
Sherwood Waterproofing Corp., 53 Park Pl., New York City.

PENSTOCKS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

pH METERS & pH TESTERS
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

PIPE, ACID PROOF
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Corning Glass Works, Corning, N. Y.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

PIPE AND TANK COATINGS
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Koppers Co., Tar & Chemical Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PIPE, ASBESTOS-CEMENT
Asbestos-Cement Pipes, Inc., 225 Broadway, New York City.
Johns-Manville Co., 22 E. 40th St., New York City.

PIPE, BRASS AND COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Brass Co., Port Huron, Mich.

PIPE, CAST IRON
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 4th Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CAST IRON SERVICE
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Warren Foundry & Pipe Co., 11 Broadway, New York City.

PIPE, CEMENT LINED
American Cast Iron Pipe Co., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
United States Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

PIPE, CONCRETE, PRESSURE
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Association, 33 W. Grand Ave., Chicago, Ill.

PIPE, COPPER
American Brass Co., Waterbury, Conn.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Farnan Brass Works Co., P. O. Box 6147, Cleveland, Ohio.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.

PIPE, CORRUGATED
Armco Drainage Products Assn., Middletown, Ohio.

PIPE, CULVERT
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE CUTTING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE ENAMELS, PROTECTIVE—COAL TAR
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York City.

PIPE, FELT WRAPPING
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PIPE FITTINGS
American Cast Iron Pipe Co., Birmingham, Ala.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Carson-Cadillac Corp., Birmingham, Ala.
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
M. & H. Valve Fittings Co., Anniston, Ala.
Mueller Brass Co., Port Huron, Mich.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., Philadelphia, Pa.

PIPE—GALVANIZED, LIGHT-WEIGHT
(Quick Coupling, Transportable for Conveying Water)
Champion Corp., Hammond, Ind.

PIPE, GLASS
Corning Glass Works, Corning, N.Y.

PIPE JOINT COMPOUNDS
Atlas Mineral Products, Mertztown, Pa.
The Barrett Co., 40 Rector St., New York City, N. Y.
Hydraulic Development Corp., 50 Church St., New York City.
Leadite Co., Philadelphia, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

PIPE JOINTS, MECHANICAL
Carson-Cadillac Corp., Birmingham, Ala.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
L. A. Weston, Adams, Mass.

PIPE JOINT TOOLS
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Hydraulic Development Corp., 50 Church St., New York City.
Mueller Co., Decatur, Ill.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Servicised Products Corp., 6051 W. 65th St., Chicago, Ill.

PIPE, LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

PIPE LOCATORS
Globe Phone Mfg. Co., 517 Chanin Bldg., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

PIPE PUSHERS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, SEWER
American Cast Iron Pipe Co., Birmingham, Ala.
Armco Drainage Products Assn., Middletown, Ohio.
Cast Iron Pipe Research Corp., 122 S. Michigan Ave., Chicago, Ill.
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill. (Reinforced Concrete)
U. S. Pipe & Foundry Co., Burlington, N. J.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

PIPE, STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, SUBAQUEOUS
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Johns-Manville, 22 E. 40th St., New York City.
Lock Joint Pipe Co., Ampere, N. J.
U. S. Pipe & Foundry Co., Burlington, N. J.

PIPE TAPPING MACHINES
Crane Co., 826 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

PIPE TEST PLUGS
Northrop & Co., Inc., 50 Church St., New York City.

PIPE, WELDED STEEL
American Rolling Mill Co., Middletown, Ohio.
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

PIPE, WRAPPING
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.

PITOT TUBES
Pitometer Company, 50 Church St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

PNEUMATIC CONVEYORS FOR WATER AND SEWAGE TREATMENT
Dracco Corp., Cleveland, Ohio.
Fuller Co., Catasauqua, Pa.

POROUS TUBES AND PLATES
Carborundum Co., Niagara Falls, N. Y.

POTENTIOMETERS
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

PRESSURE REGULATORS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

PROPORTIONING EQUIPMENT (CHEMICAL)
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.

Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St. Chicago, Ill.
International Filter Co., 325 W. 25th St., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

PUMP MOTOR STARTERS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

PUMP PRIMERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.

PUMPS, ACID-HANDLING
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Hills-McCanna Co., 2349 Nelson St. Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.
Worthington Pump, Harrison, N.J.

PUMPS, BOILER FEED
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump, Harrison, N.J.

PUMPS, CELLAR DRAINER
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Worthington Pump, Harrison, N.J.

PUMPS, CENTRIFUGAL
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Homelite Corp., Port Chester, N. Y.
Layne & Bowler, Inc., Memphis, Tenn.
Northrop & Co., 50 Church St., New York City.
Worthington Pump, Harrison, N.J.

PUMPS, CONDENSATION
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Worthington Pump, Harrison, N.J.

PUMPS, DEEP WELL
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Worthington Pump, Harrison, N.J.

PUMPS, DIAPHRAGM
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Edson Corp., 49 D St., South Boston, Mass.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th St., Chicago, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

PUMPS, DRAINAGE
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
S. Morgan Smith Co., York, Pa.
Worthington Pump, Harrison, N.J.

PUMPS, GAS
(For CO_2 and Other Gases)
Roots - Connersville Blower Corp., Connersville, Ind.

PUMPS, HYDRANT
Edson Corp., 49 D St., South Boston, Mass.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.

PUMPS, JETTING
Northrop & Co., Inc., 50 Church St., New York City.

PUMPS, PORTABLE
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 So. Michigan Ave., Chicago, Ill.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Worthington Pump, Harrison, N.J.

PUMPS, PRIMING
Roots - Connersville Blower Corp., Connersville, Ind.

PUMPS, ROTARY
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Roots - Connersville Blower Corp., Connersville, Ind.
Worthington Pump, Harrison, N.J.

PUMPS, SELF PRIMING
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
De Laval Steam Turbine Co., Trenton, N. J.
Homelite Corp., Port Chester, N. Y.
Northrop & Co., 50 Church St., New York City.
Worthington Pump, Harrison, N.J.

PUMPS SEWAGE
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
Worthington Pump, Harrison, N.J.

PUMPS, SLUDGE
American Well Works, Inc., Aurora, Ill.
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Gardner-Denver Co., Quincy, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.
Worthington Pump, Harrison, N.J.

PUMPS, SUCTION AND FORCE
Ralph B. Carter Co., 53 Park Place, New York City.
Edson Corp., 49 D St., South Boston, Mass.
Northrop & Co., 50 Church St., New York City.
Worthington Pump, Harrison, N.J.

PUMPS, SUMP
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Worthington Pump, Harrison, N.J.

PUMPS, TURBINE
De Laval Steam Turbine Co., Trenton, N. J.
Fairbanks, Morse & Co., 600 S Michigan Ave., Chicago, Ill.
Layne & Bowler, Inc., Memphis, Tenn.
Roots - Connersville Blower Corp., Connersville, Ind.
Worthington Pump, Harrison, N.J.

PUMPS, VACUUM
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Fuller Co., Catasauqua, Pa.
Gardner-Denver Co., Quincy, Ill.
Roots - Connersville Blower Corp., Connersville, Ind.
Vogt Brothers Mfg. Co., Louisville, Ky.
Worthington Pump, Harrison, N.J.

RATE OF FLOW CONTROLLERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RATE OF FLOW RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Neptune Meter Co., 50 W. 50th St. New York City.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.

REAMERS
Mueller Co., Decatur, Ill.

RECARBONATORS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Ozark Chemical Co., Ozark, Okla.
Permutit Co., 330 W. 42nd St., New York City.
Vogt Mfg. Co., Louisville, Ky.

RECORDING INSTRUMENTS
Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland, Ohio.
F. S. Brainard & Co., 246 Palm St., Hartford, Conn.
Builders Iron Foundry, 9 Coddington St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

RECUPERATOR
Carborundum Co., Perth Amboy, N. J.

REFRACTORIES
Carborundum Co., Perth Amboy N. J.
Johns-Manville, 22 E. 40th St., New York City.

REGULATORS, SEWAGE
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

REGULATORS (Pressure), WATER AND GAS
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia Pa.

RESERVOIRS
(See Standpipes and Tanks)

ROBOT FILTER AND SOFTENER OPERATORS
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

RUST PREVENTION
(Tanks, Pipe Lines, Submerged Metal)
The Barrett Co., 40 Rector St., New York City, N. Y.
Electro Rust-Proofing Co., Third National Bldg., Dayton, Ohio (Cathodic Protection)
General Paint Corp., 3091 Mayfield Rd., Cleveland, Ohio.
Koppers Co., Tar & Chemical Div., Pittsburgh, Pa.
Philadelphia Quartz Co., Philadelphia, Pa.
Reilly Tar & Chemical Co., Merchants Bank Bldg., Indianapolis, Ind.

SADDLES, PIPE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

SAMPLERS AND SAMPLING TABLES
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Mfg. Co., Darby, Pa.
R. W. Sparling, 945 N. Main St., Los Angeles, Calif.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SAND EXPANSION INDICATORS
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

SCREENS, INTAKE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SAND, GRAVEL AND STONE
Dorr Co., 570 Lexington Ave., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Link-Belt Co., 300 W. Pershing Rd., Chicago, Ill.

SCREENS, SEWAGE
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SCREENS, WATER WELL
Layne & Bowler, Inc., Memphis, Tenn.

SCREW PLUGS—(REMOVABLE FOR MAINS)
W. H. Rapp, P. O. Box 584, Atlanta, Ga.

SERVICE BOXES
Central Foundry Co., 386 Fourth Ave., New York City.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.

SEWAGE DISPOSAL FLOOR SYSTEM
Ayer-McCarel-Reagan Clay Co., Brazil, Ind.
Bowerston Shale Co., Bowerston, Ohio.

SEWAGE EJECTORS
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.

SEWAGE SAMPLERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Everson Mfg. Co., 214 W. Huron St., Chicago, Ill.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SEWAGE SCREENING GRINDERS
Chain Belt Co., Milwaukee, Wis.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., Kingston, Pa.

SEWAGE SLUDGE INCINERATOR
Dorr Co., 570 Lexington Ave., New York City.
Nichols Engineering & Research Corp., 60 Wall Tower, New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Underpinning & Foundation Co., 155 E. 44th St., New York City.

SEWER CLEANERS
Champion Corp., Hammond, Ind.
Petersen Hydraulic Flusher Co., 617 S. Sixth St., Milwaukee, Wis.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SEWER DESIGN—CONCRETE
(Literature, Information, Advice)
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

SEWER PIPE
(See Pipe, Sewer)

SEWER PIPE JOINTS
Atlas Mineral Prod. Co., Mertztown, Pa.
Hydraulic Development Corp., 50 Church St., New York City.
Servicised Prod. Corp., 6051 W. 65th St., Chicago, Ill.
L. A. Weston, Adams, Mass.

SEWER RODS
Champion Corp., Hammond, Ind.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
W. H. Stewart, P. O. Box 767, Syracuse, N Y.
Turbine Sewer Machine Co., 5210 W. State St., Milwaukee, Wis.

SIGHT FEEDERS
(For Chemical Pumps)
Proportioneers, Inc., 9 Codding St., Providence, R. I.

SIGHT GLASSES
Corning Glass Works, Corning, N. Y. (Pyrex Brand)

SIGNALS, BIN
Fuller Co., Catasauqua, Pa.

SIPHONS (SEWAGE)
Armco Drainage Products, Assn., Middletown, Ohio.
Ralph B. Carter Co., 53 Park Place, New York City. (Alternating.)
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SLEEVES, PIPE REPAIR
Cast Iron Pipe Research Assn., 122 S. Michigan Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Warren Foundry & Pipe Co., 11 Broadway, New York City.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

SLEEVES, TAPPING (VALVE)
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
M. & H. Valve & Fittings Co., Anniston, Ala.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.

SLUDGE COLLECTORS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Filtration Equipment Corp., 10 E. 40th St., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Oh'o.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.

SLUDGE DEWATERING
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.

SLUDGE DISINTEGRATORS
Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo.
Jeffrey Mfg. Co., Columbus, Ohio.
Royer Foundry & Mach. Co., 158 Pringle St., Kingston, Pa.

SLUDGE FILTERS (VACUUM)
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Filtration Equipment Corp., 10 E. 40th St., New York City.

SLUDGE GAS PURIFIERS
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.

SLUDGE PUMPS
Ralph B. Carter Co. ,53 Park Place, New York City.
Chicago Pump Co., 2349 Wolfram St., Chicago, Ill.
Dorr Co., 570 Lexington Ave., New York City.
Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

SODA ASH
The Columbia Alkali Corp., Barberton, Ohio.
Diamond Alkali Co., Pittsburgh, Pa
Electro Bleaching Gas Co., 60 E. 42nd St., New York City.
Innis, Speiden & Co., 117 Liberty St., New York City.
Mathieson Alkali Works, 60 E. 42nd St., New York City.
Penn. Salt. Mfg. Co., Widener Bldg., Philadelphia, Pa.
Solvay Sales Corp., 40 Rector St., New York City.

SODIUM ALUMINATE
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., Widener Bldg., Philadelphia, Pa.

SODIUM SILICATE
Diamond Alkali Co., Pittsburgh, Pa
General Chemical Co., 40 Rector St., New York City.
Philadelphia Quartz Co., Philadelphia, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Standard Silicate Division, Diamon Alkali Co., Pittsburgh, Pa.

SOFTENERS AND PURIFIERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Everson Mfg. Co. 214 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

SPEED REDUCERS, TRANSMISSION
De Laval Steam Turbine Co., Trenton, N. J.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

SPRINKLING FILTER PLANTS
Ralph B. Carter Co., 53 Park Place, New York City.
Dorr Co., 570 Lexington Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

STACKS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

STACKS, FUME
Johns-Manville, 22 E. 40th St., New York City.

STANDPIPE AND TANKS
Chicago Bridge & Iron Company, 2198 Old Colony Bldg., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STANDPIPE PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., Third National Bldg., Dayton, Ohio.

STIRRERS (LABORATORY)
Dorr Co., 570 Lexington Ave., New York City.
Omega Mach. Co., Inc., 4010 Penn Ave., Kansas City, Mo.

STOKERS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago, Ill.
Link-Belt Co., 2410 W. 18th St., Chicago, Ill.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

STORAGE TANKS
Chicago Bridge & Iron Co., 2198 Old Colony Bldg., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Portland Cement Assn., 33 W. Grand Ave., Chicago, Ill.

STRAINERS, SUCTION
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

SULPHATE OF ALUMINA
Activated Alum Corp., Curtis Bay, Baltimore, Md.
General Chemical Co., 40 Rector St., New York City.
Monsanto Chemical Co., St. Louis, Mo.
Monsanto Chemical Co., Merrimac Div., Boston, Mass.
Penn. Salt Mfg. Co., 1000 Widener Bldg., Philadelphia, Pa.

SULPHUR REMOVAL
(See Gas Purification)

SUPER-CHLORINATION UNITS
(See Chlorinators)

SWIMMING POOL EQUIPMENT
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Ralph B. Carter Co., 53 Park Place, New York City.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit Co., 330 W. 42nd St., New York City.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilson Chemical Feeders, Inc., 110 Washington St., Buffalo, N. Y.

SWIMMING POOL TESTING OUTFITS (pH and Chlorine)
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Phipps & Bird, Inc., 915 E. Cary St., Richmond, Va.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.
Wilson Chemical Feeders, Inc., Buffalo, N. Y.

SWITCHES, FLOAT, TRANSFER AND REMOTE CONTROL
Clark Controller Co., 1146 E. 152nd St., Cleveland, Ohio.

TANKS, ELEVATED STEEL
Chicago Bridge & Iron Company 2198 Old Colony Bldg., Chicago Ill.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Norwalk Tank Co., Inc., 1 No. Water St., So. Norwalk, Conn.
Pittsburgh-Des Moines Steel Co., Pittsburgh, Pa.

TANK PRESERVATION
(Cathodic Protection Process)
Electro Rust-Proofing Co., Third National Bldg., Dayton, Ohio.

TANK ROOFS—CONCRETE Z—D
Roberts & Schaefer Co., 307 N. Michigan Ave., Chicago, Ill.

TANKS, RUBBER LINED
Atlas Mineral Products Co., Mertztown, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
Wallace & Tiernan Co., Inc., Newark, N. J.

TANKS, STEEL
(See Tanks, Elevated Steel)

TAPPING MACHINES
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Mueller Co., Decatur, Ill.

TASTE & ODOR CONTROL GRAPHS
Darco Corp., 60 E. 42nd St., New York City.

TASTE & ODOR REMOVAL CHEMICALS
Activated Alum Corp., Curtis Bay, Baltimore, Md.
Cloroben Corp., 90 Forrest St., Jersey City, N. J.
Darco Corp., 60 E. 42nd St., New York City.
Industrial Chemical Sales Div., West Virginia Pulp & Paper Co., Inc., 230 Park Ave., New York City.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
L. A. Salomon & Bro., 216 Pearl St., New York City.
Wallace & Tiernan Co., Inc., Newark, N. J.

TESTERS, WATER METER
Ford Meter Box Co., Wabash, Ind.
Mueller Co., Decatur, Ill.
National Meter Co., 4221 First Ave., Brooklyn, N. Y.
Neptune Meter Co., 50 W. 50th St., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

THICKENERS
Ralph B. Carter Co., 53 Park Place, New York City.
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
The Eimco Corp., 634 S. Fourth West St., Salt Lake City, Utah.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.

TOOLS, SPECIAL
Benton Tool Corp., 426 Engineers Bldg., Cleveland, Ohio.

TREADS, SAFETY
Arrowhead Iron Works, Kansas City, Mo.

TRICKLING FILTERS, HIGH RATE, HIGH CAPACITY
Chain Belt Co., Milwaukee, Wis.
Dorr Co., 570 Lexington Ave., New York City.
Lakeside Engrg. Co., 222 W. Adams St., Chicago, Ill.
Link Belt Co., 307 N. Michigan Ave., Chicago, Ill.

TRITURATORS
(See also Grinders)
Chain Belt Co., Milwaukee, Wis.

TUNNEL LINER PLATES
Armco Drainage Prod. Assn., Middletown, Ohio.

TUNNEL MACHINERY, BORING & LINING
The Eimco Corp., 634 So. Fourth West St., Salt Lake City, Utah.
Jeffery Mfg. Co., Columbus, Ohio.

TURBINES, HYDRAULIC
De Laval Steam Turbine Co., Trenton, N. J.
S. Morgan Smith Co., York, Pa.

TURBINES, STEAM
De Laval Steam Turbine Co., Trenton, N. J.
Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.
Worthington Pump, Harrison, N.J.

VALVE BOXES
Central Foundry Co., 386 Fourth Ave, New York City.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Ford Meter Box Co., Wabash, Ind.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Modern Iron Works, Quincy, Ill.
Mueller Co., Chattanooga, Tenn.

Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES
Armco Drainage Products Assn., Middletown, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve & Mfg. Co., P. O. Box 595, Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.
Vogt Bros. Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, AIR RELEASE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, AIR & VACUUM
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
R. D. Wood Co., 400 Chestnut St., Chicago, Ill.

VALVES, ALTITUDE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 So. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve & Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa.
S. Morgan Smith Co., York, Pa.

VALVES, CHECK
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., Philadelphia, Pa.

VALVES, CHLORINE
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Everson Mfg. Co., 233 W. Huron St., Chicago, Ill.
Wallace & Tiernan Co., Inc., Newark, N. J.

VALVES, CONE, OF ALL TYPES
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, EMERGENCY TRIP
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.

VALVES, FLAP
Brown & Brown, Inc., 456 S. Main St., Lima, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FLOAT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.

VALVES, FOOT
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave. Chicago, Ill.
Edson Corp., 49 D St., South Boston, Mass.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Chattanooga, Tenn.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, FOUR WAY
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Roberts Filter Mfg. Co., Darby, Pa.

VALVES, GATE
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Bartlett-Hayward Div., Koppers Co., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
Vogt Brothers Mfg. Co., Louisville, Ky.
R. D. Wood Co., Philadelphia, Pa.

VALVES, HYDRAULIC CYLINDER OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MOTOR OPERATED
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Koppers Co., Bartlett - Hayward Div., Baltimore, Md.
Ludlow Valve Mfg. Co., Troy, N. Y.
Merco Nordstrom Valve Co., 400 N. Lexington Ave., Pittsburgh, Pa.
Mueller Co., Chattanooga, Tenn.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.
R. D. Wood Co., 400 Chestnut St., Philadelphia, Pa.

VALVES, MUD AND PLUG
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
M. & H. Valve & Fittings Co., Anniston, Ala.
Mueller Co., Chattanooga, Tenn.
Vogt Brothers Mfg. Co., Louisville, Ky.

VALVES, PRESSURE REDUCING
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Mueller Co., Decatur, Ill.
Northrop & Co., Inc., 50 Church St., New York City.
Rensselaer Valve Co., Troy, N. Y.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith, York, Pa.

VALVES, RELIEF
Chapman Valve Mfg. Co., Indian Orchard, Mass.
Cochrane Corp., 17th St., & Allegheny Ave., Philadelphia, Pa.
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.
Ludlow Valve Mfg. Co., Troy, N. Y.
Mueller Co., Decatur, Ill.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, RUBBER, GLASS AND LEAD LINED
Crane Co., 836 S. Michigan Ave., Chicago, Ill.
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Hills-McCanna Co., 2349 Nelson St., Chicago, Ill.
Iowa Valve Co., Hubbell Bldg., Des Moines, Ia.

VALVES, SPECIAL AUTOMATIC
Crane Co., 836 S. Michigan Ave., Chicago, Ill
Golden-Anderson Valve Spec. Co., 1329 Fulton Bldg., Pittsburgh, Pa.
Northrop & Co., Inc., 50 Church St., New York City.
Ross Valve Mfg. Co., P. O. Box 595, Troy, N. Y.
Rensselaer Valve Co., Troy, N. Y.
S. Morgan Smith Co., York, Pa.

VALVES, WATER METER SPECIAL
Ford Meter Box Co., Wabash, Ind.

VARIABLE SPEED TRANSMISSIONS
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.

VENTURI TUBES
Bailey Meter Co., 1072 Ivanhoe, Cleveland, Ohio.
Builders Iron Foundry, 9 Codding St., Providence, R. I.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia.

VIBRATORS, ELECTROMAGNETIC
Jeffrey Mfg. Co., Columbus, Ohio
Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa.
Syntron Co., Homer City, Pa.

WASTE GAS BURNERS
Ralph B. Carter Co., 53 Park Place, New York City.
Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill.

WATER ANALYSIS EQUIPMENT AND REAGENTS
Cochrane Corp., 17th St., & Allegheny Ave., Philadelphia, Pa.
Corning Glass Wks., Corning, N. Y.
Wallace & Tiernan Co., Inc., Newark, N. J.
Wilkens-Anderson Co., 111 N. Canal St., Chicago, Ill.

WATER LEAK, LOCATING INSTRUMENTS
Globe Phone Mfg. Co., 517 Chanin Bldg., New York City.
Northrop & Co., Inc., 50 Church St., New York City.
Pitometer Co., 50 Church St., New York City.
Jos. G. Pollard Co., Inc., 151 Ashland Pl., Brooklyn, N. Y.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.
Water Leak Detector Co., 166 N. Third St., Columbus, Ohio.

WATER LEVEL RECORDERS
Bailey Meter Co., 1072 Ivanhoe Rd., Cleveland, Ohio.
Builders Iron Foundry Co., 9 Codding St., Providence, R. I.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Electric Indicator Corp., P. O. Box 476, Stamford, Conn.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Simplex Valve & Meter Co., 68th and Upland Sts., Philadelphia, Pa.

WATER MAIN CLEANING
National Water Main Cleaning Co., 50 Church St., New York City.

WATERPROOF CANVAS
Wm. W. Stanley Co., Inc., 401 Broadway, New York City.

WATERPROOFING PAINTS, COMPOUNDS AND MATERIALS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
Connelly Iron Sponge & Governor Co., 3154 S. California Ave., Chicago, Ill.
General Paint Corp., Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Koppers Co., Tar & Chem. Div., Pittsburgh, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Reilly Tar & Chem Co., Merchants Bank Bldg., Indianapolis, Ind.
Sherwood Waterproofing Co., 53 Park Pl., New York City.
Wailes Dove-Hermiston Corp., 17 Battery Pl., New York Cit.

WATER SOFTENERS
E. W. Bacharach & Co., Rialto Bldg., Kansas City, Mo.
Calgon, Inc., 300 Ross Ave., Pittsburgh, Pa.
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago (lime-soda).
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Municipal Service Co., 532 Dwight Bldg., Kansas City, Mo.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Permutit, Inc., 330 W. 42nd St., New York City.
Proportioneers, Inc., 9 Codding St., Providence, R. I.
Roberts Filter Co., Darby, Pa.

WATER WASTE SURVEYS
Pitometer Co., 50 Church St., New York City.

WEATHERPROOF PAINTS, ROOF COATINGS
Asphalt Products Co., Inc., Syracuse, N. Y.
The Barrett Co., 40 Rector St., New York City, N. Y.
General Paint Corp., 3091 Mayfield Road, Cleveland, Ohio.
Johns-Manville, 22 E. 40th St., New York City.
Tar & Chem. Div., Koppers Co., Pittsburgh, Pa.
Master Builders Co., 7016 Euclid Ave., Cleveland, Ohio.
Reilly Tar & Chem. Co., Merchants Bank Bldg., Indianapolis, Ind.

WEIGH FEEDER MACHINES
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Jeffrey Mfg. Co., Columbus, Ohio.
Omega Machine Co., 4010 Penn Ave., Kansas City, Mo.
Syntron Co., Homer City, Pa.

WELL WATER SUPPLY SYSTEMS
Crane Co., 836 S. Michigan Ave., Chicago, Ill.

WRAPPING, PIPE
(See Pipe, Wrapping)

ZEOLITE AND ZEOLITE SOFTENERS
Cochrane Corp., 17th St. & Allegheny Ave., Philadelphia, Pa.
Graver Tank & Mfg. Co., Inc., East Chicago, Ind.
International Filter Co., 325 W. 25th Pl., Chicago, Ill.
Lakeside Engrg. Corp., 222 W. Adams St., Chicago, Ill.
Permutit Co., 330 W. 42nd St., New York City.
Roberts Filter Mfg. Co., Darby, Pa.

INFORMATION ON WATER AND SEWAGE WORKS PROBLEMS* —WHERE TO FIND IT

By L. H. ENSLOW
Editor WATER WORKS AND SEWERAGE

The subject which has been assigned me is of a rather large order and will be dealt with only in part. I will content myself with stating where information of various sorts may be found.

It goes without saying that information required by water works men and sewage works operators is not concentrated in two or three books. The nearest approach to concentrated information for water works men is found in the manual published by the American Water Works Association—"Water Works Practice."

Regardless of the availability of published information, reference books, etc., it is well known that practical experience is essential in solving most water and sewage problems.

Reference Works. Text books, manuals, hand-books, journals, and catalogs are named in the attached list of recommended reference work for water sewage works men.

The list represents the majority opinions of operating men, managers, engineers and chemists. I was somewhat reticent about taking the sole responsibility of naming such a list and therefore called on men fully qualified to offer suggestions to make up a set of reference works.

I had not thought of catalogs put out by manufacturers as being of value beyond use in specifying and purchasing materials and equipment, but one of my collaborators who is Superintendent of Operations of a company operating a large number of plants states the following:

"I find that in my own work the most frequently consulted books are the catalogs of the manufacturers of water works materials and equipment. These catalogs are of constant use, not only in connection with the purchasing of the goods listed, but also due to the vast amount of information contained in them as to the available styles, weights, dimension, capacities, and many other features."

Small Works and Large Works. It had been my thought that I might make up a list of reference works which would cover the needs of managers and operators of small and medium sized works and another which would be more extensive for the larger works. A superintendent of a small works writes as follows, and I am forced to agree with him to a major degree.

"In my opinion, the small town superintendent should have just as complete knowledge of fundamentals as the large town superintendent and in fact would have problems coming to his personal attention which might require more detailed knowledge than would be the case with the superintendent of a large system who would delegate such work to various assistants."

Current Information. Current information is best obtained through the technical journals, trade papers, manufacturers' publications.

Attending meetings, listening to papers read and discussion of these, is of paramount value. Demonstrations such as those put on during meetings are extremely valuable and operations of this nature can not, as a rule, be found described in books. Operating papers in the journals and trade publications, however, frequently describe "operating kinks" of a great value.

Reprints and Bulletins. Manufacturers and Trade Associations frequently distribute information of value in the nature of reprinted articles, house-organs or bulletins. Ofttimes these are mailed out only upon request, or by sending in a coupon incorporated in an advertisement. It therefore pays to read the ads.

Such publications usually contain valuable information and often serve a very useful purpose. If they are not bulky these may be filed away or placed in a loose leaf binder under the heading of the subject matter, as for example, "Meters and Meter Maintenance," "Tanks and Standpipes," "Water Treatment," "Algae Control," etc., etc. If bulky, they may be torn apart and the most valuable parts filed for future reference It is surprising how much worthwhile information and data can thus be accumulated in a readily available form and at practically no cost. Some men make a practice of tearing apart technical magazines and filing the desired contents under subject matter heading where the information will be more readily available thereafter.

Filing Schemes. I have found the following filing schemes practical, serviceable and inexpensive:

For the office, the old fashioned and inexpensive box letter-file, made of cardboard and wood, is very useful. The index is removed and the clippings, reprints, etc., covering a single "subject-head" are placed in envelopes or folders properly labeled and preserved in the box files. These boxes are properly labeled to show their subject matter contents and stored on end on a shelf as one would store a set of books. As the contents of a single box grows it may be necessary later to devote an entire box to a single subject head. "Water Treatment" for example will probably require a single box which may contain a folder on water softening, and others on coagulation, aeration, corrosion control, etc. One subject head can be broken down into as many sub-divisions as may appear desirable. I have one which contains 16 sub-divisions and this assists in prompt location of the desired information when needed.

Some people may prefer to use metal box files of the same size which are also available, but more expensive. Others may prefer a set of loose leaf binders, but I find the boxes are simpler, offer more protection to the filed sheets and keep the dust out.

Information such as conversion factors, data tables and formulae which are more frequently used may best be filed in a pocket-size loose leaf book. The paper can be reinforced with little gummed linen eyelets where the rings pass through and the sheet folded if need be to fit into the binder or it may be cut into parts and glued at its corners to both sides of a filler sheet of the binder. An index in the binder serves a useful purpose in that it facilitates location of the desired tables of data or conversion figures. For work in the field the pocket size loose-leaf book is almost indispensable. I have one fairly well filled with curves and data cut from magazines, journals, and booklets distributed by manufacturers.

Short Courses for Superintendents and Operators. This scheme has been followed successfully in many states. The courses are so arranged that those taking it are not in the least embarrassed by any lack of prior education. Much of the course is of a practical nature and the chemistry and biology lectures and laboratory work are made simple and attractive. Superintendents who have attended these schools have found them very helpful and have returned to take the courses another year, which is an excellent indication of their usefulness. Materials men, factory representatives, sales engineers and other specialists are called upon to give demonstrations of important equipment used in water works systems. All of this is very useful and helpful to the manufacturer as well as the "students." Questions are freely asked and answered.

I do not hesitate to recommend the Short Course to every one of you and I believe that you will find the slight expense and the time spent a thoroughly good investment.

Special and Unusual Problems. When a special or an unusual problem presents itself to water works or sewage works operators, information required may not be easily found in published form. In such instances the State Health Department personnel can be of material help and I can assure you, as a former operator and later affiliated with two State Departments of Health, that the engineers and chemists connected with the Department are always glad to assist the operator or the management of a public works wherever they can. Call freely on your Health Department Engineer for information and advice and you will be the gainer.

In instances, the problem will be of a nature that can be solved by utilizing information obtainable through the Research

*A paper presented before the Southeastern Section, American Water Works Association. The lists appended here have been revised and brought up to date.

and Development Departments of manufacturers, Institutes, or Trade Associations. In my capacity of Research Engineer of the Chlorine Institute I have frequently been able to supply special information covering problems in chlorine application which, of nature, I was better prepared to give than someone else because of my long and intimate contact with chlorinating problems. Other associations are equipped to give similar service in connection with their products.

I have not understood why consulting engineers and chemists are not more regularly approached for advice and information covering special problems. I believe that managers of water and sewage systems overlook the value of having their municipality retain consultants on an annual fee basis in order to be in a position to seek advice as frequently as need be by mail or 'phone. This is practiced by some cities but as a rule the small municipalities, which would profit relatively more perhaps than the larger cities by such an arrangement, fail to take advantage of this relatively low cost service. Consultants are not prone to charge small municipalities as heavy as they would those more able to pay. Industry finds that it pays to retain consultants on an annual fee basis and it sems that municipalities should find the same.

I believe that every home should have its family physician and that every municipality needs the services of a consulting engineer to prescribe "remedies" over the 'phone just as the family physician does and thus frequently saves the patient much discomfort or prevents the necessity of a "major operation" later.

I find an increasing tendency on the part of small towns to retain chemists and engineers to supervise plant operations and at the same time supply advice and information whenever required. If engineers and chemists were as good salesmen as are lawyers and physicians, more of this kind of valuable service would be made use of.

Visiting. An excellent means of procuring information covering operation and maintenance is by visiting water and sewage works plants. Many of us are prone to inspect the works of our neighbors with a critical eye. We see too easily the weak points. If, on the other hand, we should look around and make inquiries in a less critical frame of mind, or with an attitude of seeking all possible information, more of value could be learned.

When one attends a water or sewage works meeting or a short course he is actually "visiting" because there he meets and tasks with men from other places. That is next in value to an actual visit or first hand inspection of the other fellow's works. I wish to stress the importance of visiting and exchanging experiences.

Acknowledgment. I acknowledge, with appreciation, the assistance of the several men who contributed suggestions ot reference books, catalogs, etc., which proved helpful in preparing the following lists:

LIST NO. 1 —FOR WATER WORKS MANAGERS AND OPERATORS

[For Small and Moderate Size Systems.]

Books	*Publishers*	*Authors*
Water Works Practice—Manual of the A. W. W. A. ($5.00)	Williams & Wilkins, Baltimore	Various
Manual of Water Works Accounting	Am. Water Works Assn., New York City	Various
Manual of Water Purification Practice (in preparation)	Am. Water Works Assn., New York City	Various
The Operation of Water Filtration Plants (F)	N. C. State Dept. Health, Raleigh, N. C.	
Water Supply Control (nominal charge)	N. Y. State Dept. Health, Albany, N. Y.	
Water Works Handbook ($7.00)	McGraw-Hill Co., New York City	Flynn, Weston & Bogert
Water Purification Control, 2nd Edition ($1.75)	Williams & Wilkins, Baltimore, Md	Hopkins
Standard Methods of Water Analysis, 8th Ed. ($2.50)	A. P. H. A., New York City	A. W. W. A. & A. P. H. A.
Lab. Manual—Chemical & Bacterial Analysis Water and Sewage, 2nd Edition ($2.50)	McGraw Hill Co., New York City	Theroux, Eldridge, Mallman
Water Purification ($7.00)	McGraw Hill Co., New York City	Ellms
Copper Sulphate in Control of Micro Organisms (F)	Nichols Copper Co., New York City	Hale
Pump Data (F)	Economy Pumping Mach. Co., Chicago	
Conversion Factors for Engineers (F)	The Dorr Co., New York City	
Engineering Data in Flow of Fluids in Pipes (F)	Crane Co., Chicago	
Bul. No. 21 (a Handbook on Hydraulics) (F)	National Tube Co., Pittsburgh, Pa	
Handbook of Cast Iron Pipe (F)	Cast Iron Pipe Research Assn., Chicago	
Chlorination of Water	John Wiley & Sons, New York City****	Race
Technical Bulletins on Chlorination (F)	Wallace & Tiernan Co., Newark, N. J	Various
Hydraulic Tables—3rd Ed. ($2.00)	John Wiley & Sons, New York City	Williams & Hazen
Handbook on Fire Protection ($4.50)	D. Van Nostrand Co., New York City	Crosby, Fiske & Forster
Fire Engine Tests and Fire Stream Tables (F)	National Board of Fire Underwriters, N. Y. C.	
Plumber's Handbook ($4.00)	McGraw-Hill Co., New York City	Dibble
Examination of Water—6th Ed. ($3.00)	John Wiley & Sons, New York City	Mason & Buswell
Public Water Supplies—3rd Ed. ($6.00)	John Wiley & Sons, New York City	Turneau & Russell
American Civil Engineering Handbook—5th Ed. ($8.00)	John Wiley & Sons, New York City	Merriman & Wiggin
Lefax—Data Sheets for Loose Leaf Note Books	Lefax, Inc., Philadelphia, Pa	Various
Water Supply & Treatment (F)	National Lime Assn., Washington, D. C.	Hoover
A. B. C. of Hydrogen Ion Control (F)	LaMotte Company, Baltimore, Md	
Modern P. H. Control (F)	W. A. Taylor Co., Baltimore, Md.	
"Hydro-tite" Booklet of Useful Information (F)	Hydraulic Development Corp., New York, N. Y	
Microscopy of Drinking Water (4th Ed. $7.00)	John Wiley & Sons, New York City	Whipple-Fair
Plane Surveying ($3.50)	John Wiley & Sons, New York City	Tracey
Water Treatment and Purification ($2.50)	McGraw Hill Co., New York City	Ryan
Water Supply & Sewerage ($5.00)	McGraw-Hill Co., New York City	Steel
"The Hardy-Cross Method"—Bul. 286	Univ. of Illinois, Eng. Explt. Sta	Hardy

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (Applies to Lists 1 and 2)

Journal and Monographs of the American Waterworks Association
Journal of the New England Water Works Association.
Current Water Works Technical Magazines and Trade Papers.

LIST NO. 2—FOR MANAGERS, CHEMISTS AND OPERATORS OF LARGE WATER WORKS

(In addition to List No. 1)

Books	*Publishers*	*Authors*
Fresh Water Biology ($7.00)	John Wiley & Sons, New York City	Ward & Whipple
Fresh Water Algae ($6.00)	McGraw-Hill Co., New York City	Smith

Elements of Water Bacteriology—5th Ed. ($2.50)	John Wiley & Sons, New York City	Prescott & Winslow
"Industrial Water Supplies" (nominal charge)	Ohio Geological Survey, Columbus, Ohio	C. W. Foulk
pH and Its Practical Application ($3.50	Williams & Wilkins Co., Baltimore, Md.	LaMotte, Kenny & Reed
Elimination of Tastes and Odors in Water ($5.00)	McGraw-Hill Co., New York City	Baylis
Boiler Feedwater Purification ($4.00)	McGraw-Hill Co., New York City	Powell
Chemistry of Water and Sewage Treatment****	Chemical Catalog Company, New York City****	Buswell
Water Borne Typhoid Fever Outbreaks (nominal)	Am. Public Health Bureau	Wolman & Gorman
Textbook of Bacteriology ($8.00)	D. Appleton & Co., New York City	Zinser & Jones
Corrosion; Causes and Prevention ($7.00)	McGraw-Hill Co., New York City	Speller
Water Supply Paper No. 658 (Quality of Waters) (nominal)	U. S. Geological Survey, Washington, D. C.	Stabler
Water Supply Engineering (3rd Ed. $6.00)	McGraw-Hill Co., New York City	Babbitt & Doland
Handbook of Hydraulics ($4.00)	McGraw-Hill Co., New York City	King
Concrete Engineers' Handbook ($6.00)	McGraw-Hill Co., New York City	Hool & Johnson
Pocket Companion (nominal)	Carnegie Steel Corp., New York City	
Business Law for Engineers ($4.00)	McGraw-Hill Co., New York City	Allen
Mechanical Engineers' Handbook—11th Ed. ($5.00)	John Wiley & Sons, New York City	Kent
Elements of Hydraulics ($1.50)	John Wiley & Sons, New York City	Merriman
Guiding Principles of Public Service Regulations (3 Vols.)	Public Utilities Reports, Inc., Rochester, N. Y.	Spurr
Theory and Practice of Public Utility Valuation****	McGraw-Hill Co., New York City****	Maltbie
Public Utility Rates****	McGraw-Hill Co., New York City****	Barker
Public Utility Rate Structures ($4.00)	McGraw-Hill Co., New York City	*Nash*
Census of Munic. Water Purification Plants (nominal)	Am. Water Works Assn., New York City	
Business Administration for Engineers ($5.00)	McGraw-Hill Co., New York City	Harding & Canfield
Census of Municipal Water Purification Plants (50c)	Am. Water Wks. Assn., New York City	
Index to Jour. of A. W. W. A.—1881-1933 ($2.50)	Am. Water Wks. Assn., New York City	

*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

For Journals see list No. 1.

LIST NO. 3*—FOR OPERATORS AND MANAGERS OF SMALL SEWAGE WORKS**

Books	*Publishers*	*Authors*
Operation and Control of Sewage Treatment Plants (F)	New York State Dept. Health	N. Y. State Dept. Health
Arithmetic of Sewage Disposal $2.00)	John Wiley & Sons, New York City	Imhoff & Fair
Sewerage and Sewage Disposal Text Book ($6.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Bulletins Nos. 59, 68, 69, 84 and 86 (F)	Iowa State College, Ames, Iowa	Various
Manual of Sewage Works Operation (nominal)	New Jersey Sewage Expt. Sta., New Brunswick, N. J.	
Reprints of Technical Papers on Chlorine in Sewage Treatment (F)	Wallace & Tiernan Co., Newark, N. J., and The Chlorine Inst., N. Y. C.	
Chlorination in Sewage Treatment (F)	Amer. Pub. Health Assn., N. Y. C.	Committee Reports
Chemical Treatment of Sewage (nominal)	Amer. Pub. Health Assn., N. Y. C.	Committee Report
Standard Methods of Water and Sewage Analysis ($2.50)	Amer. Pub. Health Assn., N. Y. C.	A. W. W. A.-A. P. H. A.
Laboratory Manual of Water and Sewage Analysis ($2.50)	McGraw-Hill Co., New York City	Theroux, Eldridge & Mallman
Sewage Works Journal—(Official publication of the Federation of Sewage Wks. Assns.)		
Current Sewerage Magazines		
Sewer Rentals ($1.50)	Am. Public Works Assn., Chicago	Various

*Revised and enlarged, Apr., 1939.

LIST NO. 4*—FOR MANAGER, CHEMISTS AND OPERATORS OF LARGE SEWAGE WORKS**

(In addition to List No. 3)

Books	*Publishers*	*Authors*
American Sewage Practice Vol. 3, Sewage Treatment (1935 Edition) ($7.00)	McGraw-Hill Co., New York City	Metcalf & Eddy
Solving Sewage Problems ($6.00)	McGraw-Hill Co., New York City	Fuller & McClintock
Sewerage and Sewage Treatment—4th Ed. ($5.00)	John Wiley & Sons, New York City	Babbitt
The Chemistry of Water and Sewage Treatment****	Chemical Catalog Co., New York****	Buswell
The Hoover Plumbing Code (B. H. 13) (nominal)	U. S. Bureau of Standards	
Sewerage and Sewage Treatment ($3.50)	Intl. Text Book Co., Scranton, Pa.	Hardenberg
Sewerage, 11th Ed. ($4.50)	John Wiley & Sons, New York City	Folwell
Sewage Disposal****	John Wiley and Sons, New York City****	Kinnicutt, Winslow & Pratt
Modern Sewage Disposal ($3.50)	Federation of Sewage Works Assns., New York City	Various
Sewers (25 shillings)	Chapman & Hall, London	Bevan and Rees

(F) Available as Free Publication at this writing, Apr., 1938.
*Revised and enlarged, Apr., 1939.
****Out of print. Try National Bibliophile Service, 347 Fifth Ave., N. Y. City.

Journals and Magazines (Applies to Lists 3 and 4)

***Note*—Sewerage men should examine Lists 1 and 2—also for several (F) publications of value to all alike—for instance, "Conversion Factors for Engineers" and the hand-books of pipe and pump data.

PART I. WATER

FLOW, FRICTION, MEASUREMENT AND POWER*

The rate of flow or the volume of water passing a cross section of a stream in a unit time is called the "discharge." If a uniform velocity at all points in the cross section of a stream were possible, there would be passing any cross section of the stream, every unit of time, a prism of water having a base equal to the cross-sectional area of the stream and a length equal to the velocity. However, due to the varying effects of friction and viscosity, the different filaments of water move with different velocities. For this reason it is common in hydraulics to deal with "mean velocities."

The discharge may be expressed in terms of the mean velocity:

$$Q = av$$

where Q = Discharge in cubic feet per second.
a = Cross-sectional area of stream in square feet.
v = Mean velocity in feet per second.

When the discharge is constant (i.e., when the same quantity of water passes any cross section of a stream during equal successive intervals of time) the flow is said to be "steady."

Flow is said to be "uniform" when there is little or no change in the cross section or velocity from point to point in a stream.

Thus uniform flow implies similarity of conditions at successive cross sections at any given instant, while steady flow involves permanency of conditions at any particular cross section.

In hydraulics the term "pressure head," "static head" or simply "head" is used to designate the vertical height of a static column of liquid which, due to its weight, would produce a pressure equivalent to the pressure in the fluid at the point in question.

The "velocity head" is the height through which a body must fall in a vacuum to acquire the velocity with which water flows in a stream. The velocity head corresponding to any velocity is equal to the static head, which (neglecting friction) could cause (or could be caused by) that velocity. The relation between velocity head and velocity may be expressed by the formula:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Flow of Water Through Orifices and Tubes

As commonly used in hydraulics, the term orifice is used to designate an opening with a closed perimeter, and of regular shape, through which water flows. If the perimeter is not closed, or if the opening flows only partially full, the orifice becomes a weir.

An orifice with prolonged sides, such as a short piece of pipe two or three diameters in length, set in the side of a reservoir, is called a tube. An orifice in a thick wall has the hydraulic properties of a tube.

The theoretical velocity of a stream or jet of water issuing from an orifice is given by the formula:

$$v_t = \sqrt{2gh}$$

where v_t = Theoretical velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.
h = Head on the center of the orifice in feet.

The actual velocity of the jet is less than the theoretical velocity because of the frictional loss which occurs as the water approaches the orifice. The ratio of the actual mean velocity, v, to the theoretical velocity, v_t, is called the "velocity coefficient" and is designated by the symbol C_v. The actual mean velocity of the jet is therefore:

$$v = C_v\sqrt{2gh}$$

The stream or jet issuing from an orifice is not in all cases the same size as the opening of the orifice because of contraction effects in certain cases and flaring effects in other cases. The "contraction coefficient," C_c, of an orifice is the ratio of the cross-sectional area of the jet to that of the orifice.

The discharge from an orifice is given by the formula:

$$Q = C_vC_ca\sqrt{2gh}$$

where Q = Discharge in cubic feet per second.
a = Area of orifice opening in square feet.

It is customary to combine the coefficients C_v and C_c into a single coefficient C_d which is called a "discharge coefficient." The discharge coefficient is therefore a product of the velocity coefficient and the contraction coefficient, or $C_d = C_v \times C_c$.

The formula for discharge from an orifice then becomes:

$$Q = C_da\sqrt{2gh}$$

Table 12 gives average values of discharge coefficients for various types of orifices and tubes.

Flow of Water in Pipe and Open Channels

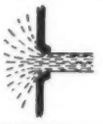
As the term is used in hydraulics, a pipe may be defined as a closed conduit which flows full under pressure. By open channel is meant any kind of water course with the top surface of the flowing water exposed to the atmosphere, such as a canal, aqueduct, flume, sewer or river.

The "wetted perimeter" of any conduit is that portion of the perimeter of the cross section of the conduit in contact with the liquid.

The "hydraulic radius" of a conduit is the cross-sectional area of the stream, divided by the wetted perimeter of that section. For a circular pipe flowing either full or half full the hydraulic radius is one-fourth the pipe diameter (or one-half the pipe radius).

If a tube is tapped into the wall of a vessel or pipe containing water under pressure, the water will rise in the tube to a height equal to the head producing the pressure at the point where the tube is inserted. Such a tube is called a "piezometer" tube. Piezometer tubes measure pressure above atmospheric pressure (gage pressure) since the water surface in the tube is subjected to atmospheric pressure. When piezometer tubes are used to measure pressure heads in pipes where water is in mo-

Table 12
Discharge Coefficients for Various Types of Orifices and Tubes

Diagram	Description	Average discharge coefficient, C_d
	SHARP-EDGED ORIFICE The stream is contracted to about 0.62 of the area of the opening.	0.61
	**ORIFICE WITH WELL-ROUNDED ENTRY** There is little or no contraction and the stream is about the same size as the opening.	0.98
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When flowing full. When the length of the tube is 2½ diameters it is called a "standard short tube".	0.82
	SHORT TUBE OR ORIFICE IN THICK WALL WITH SQUARE-EDGED ENTRY When the stream springs clear from the tube at the upstream corner the flow is the same as for a sharp-edged orifice.	0.61
	RE-ENTRANT TUBE Length about 2½ diameters. Flowing full.	0.73
	RE-ENTRANT TUBE When the length is about one diameter it is called "Borda's Mouthpiece". Stream springs clear of the walls of the tube.	0.52

*The material under this heading has been drawn from National Tube Company's Technical Bulletin No. 21.

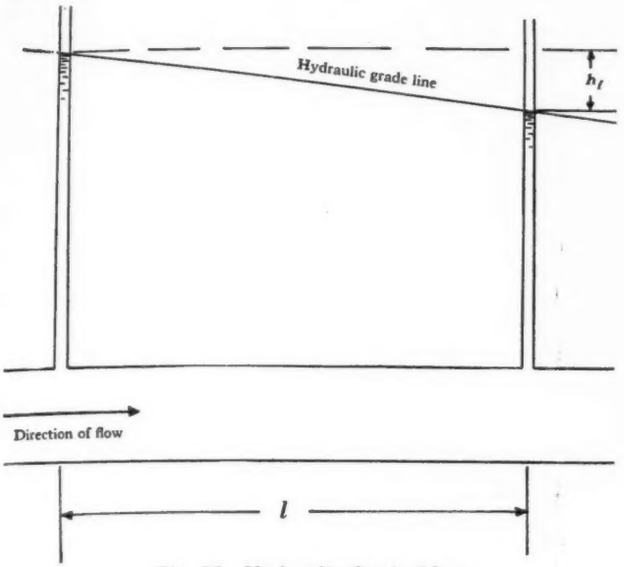


Fig. 35—Hydraulic Grade Line

tion, the end of the tube should enter the pipe at right angles to the direction of flow and the end of the tube should be flush with the inner surface of the pipe.

If a pipe full of water is provided with several piezometer tubes, a line joining the tops of the columns of water in the tubes is called the "hydraulic grade line," and the slope of this line is the "hydraulic slope" or simply the "slope." Two piezometer tubes attached to a pipe line are shown in Fig. 35. The line joining the tops of the columns of water in the tubes represents the hydraulic grade line and h_f represents the loss of head in length l. The hydraulic slope, s, is therefore:

$$s = \frac{h_f}{l}.$$

Friction

There is always friction between moving water and the surface with which the water comes into contact. There is also friction between the moving particles of the water themselves which is commonly called viscosity.

Water particles in contact with the conduit surface are retarded by friction, and viscosity causes a retardation of the particles removed from the conduit surface. Therefore, water flowing in a pipe has its maximum velocity at the center and its minimum velocity near the pipe walls.

If there were no friction losses, the theoretical velocity, v_t, at which water would discharge from a pipe or channel would be $v_t = \sqrt{2gh}$. In any long pipe or channel, however, the greater portion of the total head is used in overcoming friction.

The amount of frictional resistance offered by any surface increases with the degree of roughness of the surface. The resistance due to viscosity decreases as the temperature of the water increases.

The loss of head due to the combined effects of viscosity and friction between the moving water and the surface of the conduit is usually referred to as the loss of head due to friction.

The influences of friction and viscosity on the flow of water have been determined experimentally by various authorities and a variety of formulas for the loss of head due to friction have been derived. Only a few of the best-known and most generally used formulas will be presented in this article.

In addition to the loss of head due to friction, other losses of head result from changing the velocity or direction of flow. These special losses are considered in Table 21.

Formulas for Flow of Water In Pipe and Open Channels

The Chezy Formula

The most generally used formula for determining the velocity of flow of water in pipe and open channels is the Chezy Formula:

$$v = c\sqrt{rs}, \text{ or } v = cr^{0.5}s^{0.5}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = A coefficient which Chezy considered to be constant, but which is now known to vary with the hydraulic slope and hydraulic radius as well as with the degree of roughness of the surface with which the water comes in contact.

This formula, although originally designed for open channels, is with proper modification applicable to either open channels or pipe.

The Hazen-Williams Formula

For the same degree of roughness, the value of c for the Chezy Formula increases with the hydraulic slope and with the hydraulic radius. This is due to the fact that the exponents used for the terms in the formula are less than the true values. If the exponents were increased to correspond more nearly with the facts, the variation in the value of c would become smaller.

The Hazen-Williams Formula was designed with a view of obtaining a minimum variation in the value of c for all conduits of the same degree of roughness. That is, the object was to select values for the exponents such that c would be, as nearly as practicable, a function of the degree of roughness of the conduit surface and not of the hydraulic radius and slope.

The Hazen-Williams Formula is:

$$v = cr^{0.63}s^{0.54}0.001^{-0.04}$$

where v = Mean velocity in feet per second.
r = Hydraulic radius in feet.
s = Hydraulic slope in feet per foot of length.
c = Hazen-Williams coefficient of roughness.

The last term ($0.001^{-0.04}$) is a constant, and was introduced simply to equalize the value of c with the value in the Chezy Formula and other exponential formulas which may be used as a slope of 0.001 instead of at a slope of 1. Since $0.001^{-0.04}$ equals 1.318, the Hazen-Williams Formula may be written:

$$v = 1.318cr^{0.63}s^{0.54}$$

Values of Coefficient "C"

The following values of the coefficient c may be used in the Hazen-Williams Formula for computing the loss of head due to friction in new well-laid pipe:

Kind of Pipe	Coefficient c	Kind of Pipe	Coefficient c
National Duroline	148*†	Wood Stave	120
Wrought Steel	140	Riveted Steel	110
Small Brass and Copper	130	Vitrified Pipe	110
Cast Iron	130	Brick Sewers	100
Concrete	120		

*"Duroline" pipe is protected against internal corrosion and mounting friction losses by a cement base composition lining of a highly durable nature.—Ed.

†Approximately the same for cement lined pipe.—Ed.

It must be understood that these values depend upon the smoothness and regularity of the surfaces and are likely to vary in individual cases. In designing a pipe line it is customary to use somewhat lower coefficients than those above, to allow for variations due to local conditions, and for reduction of carrying capacity with age due to roughening of the inside surface, accumultaion of corrosion products, and tuberculation. However, in case of Duroline Pipe, the volume of flow remains practically unchanged over long periods of service due to the fact that rust tubercles do not form and the initially smooth inside surface is retained.

Tables 15 and 16 have been prepared to furnish directly the loss of head (h_f) in feet per 1000 feet of pipe of various sizes for different velocities and values of the coefficient c. Similar data for Duroline Pipe, based on a value of $c = 148$, is given in Table 17. These tables were calculated for actual internal diameters by the following arrangement of the Hazen-Williams Formula:

$$h_f = 1000\sqrt[0.54]{\frac{v}{1.318\,cr^{0.63}}}$$

where h_f = Loss of head in feet due to friction per 1000 feet of pipe = $1000s$.

The loss of head (h_f) for any value of the coefficient c not given in Tables 15 and 16 may be determined by multiplying the loss of head (h_f) for $c = 100$ by the factor $\sqrt[0.54]{\frac{100}{c}}$

Values of this factor corresponding to various values of the coefficient c are given below:

Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$	Coefficient c	Factor $= \sqrt[0.54]{\frac{100}{c}}$
60	2.575	110	0.8382
70	1.936	120	.7135
80	1.512	130	.6152
90	1.215	140	.5363
100	1.000		

Table 15
Loss of Head in Pipe by Friction for National A.P.I. Line Pipe, Calculated by Hazen-Williams Formula

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=120$	$c=100$	$c=80$
1	1.049	3	4,320	1.114	6.72	8.94	12.5	18.9
		4	5,760	1.485	11.4	15.2	21.4	32.3
		5	7,200	1.856	17.3	23.0	32.3	48.8
		6	8,640	2.227	24.3	32.3	45.2	68.4
		8	11,520	2.970	41.3	55.0	77.1	117.
		10	14,400	3.712	62.5	83.1	117.	176.
		12	17,280	4.455	87.6	117.	163.	247.
		16	23,040	5.940	149.	198.	278.	421.
		20	28,800	7.425	226.	300.	421.	636.
		25	36,000	9.281	341.	454.	636.	961.
		30	43,200	11.137	478.	636.	891.	1347.
		35	50,400	12.993	636.	846.	1185.	1792.
		40	57,600	14.849	814.	1083.	1518.	2295.
1¼	1.380	4	5,760	0.858	3.01	4.01	5.61	8.49
		5	7,200	1.073	4.55	6.06	8.49	12.8
		6	8,640	1.287	6.38	8.49	11.9	18.0
		8	11,520	1.716	10.9	14.5	20.3	30.6
		10	14,400	2.145	16.4	21.9	30.6	46.3
		12	17,280	2.574	23.0	30.6	42.9	64.9
		16	23,040	3.432	39.2	52.2	73.2	111.
		20	28,800	4.290	59.3	78.9	111.	167.
		30	43,200	6.435	126.	167.	234.	354.
		40	57,600	8.580	214.	285.	399.	603.
		60	86,400	12.870	454.	603.	846.	1279.
		80	115,200	17.160	773.	1028.	1441.	2178.
1½	1.610	4	5,760	0.630	1.42	1.89	2.65	4.01
		5	7,200	.788	2.15	2.86	4.00	6.06
		6	8,640	.946	3.01	4.01	5.62	8.49
		8	11,520	1.261	5.13	6.82	9.57	14.5
		10	14,400	1.576	7.76	10.3	14.5	21.9
		12	17,280	1.891	10.9	14.5	20.3	30.6
		16	23,040	2.521	18.5	24.6	34.5	52.2
		20	28,800	3.152	28.0	37.2	52.2	78.9
		30	43,200	4.728	59.3	78.9	111.	167.
		50	72,000	7.880	153.	203.	285.	431.
		75	108,000	11.820	324.	431.	603.	912.
		100	144,000	15.759	551.	734.	1028.	1554.
		125	180,000	19.699	833.	1109.	1554.	2350.
2	2.067	6	8,640	0.574	0.892	1.19	1.66	2.51
		8	11,520	765	1.52	2.02	2.83	4.28
		10	14,400	956	2.30	3.06	4.28	6.47
		12	17,280	1 147	3.22	4.28	6.00	9.07
		16	23,040	1 530	5.48	7.30	10.2	15.5
		20	28,800	1 912	8.29	11.3	15.5	23.3
		30	43,200	2.868	17.6	23.4	32.8	49.5
		50	72,000	4.781	45.2	60.2	84.3	128.
		75	108,000	7.171	95.8	128.	179.	270.
		100	144,000	9.561	163.	217.	304.	460.
		150	216,000	14.342	346.	460.	645.	975.
		200	288,000	19.122	589.	784.	1099.	1661.

Pipe size inches	Inside diameter inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
2½	2.469	8	11,520	0.536	0.639	0.733	0.851	1.19
		10	14,400	.670	.966	1.11	1.29	1.80
		12	17,280	.804	1.35	1.55	1.80	2.53
		16	23,040	1.072	2.31	2.65	3.07	4.30
		20	28,800	1.340	3.49	4.00	4.64	6.51
		25	36,000	1 675	5.27	6.05	7.02	9.83
		50	72,000	3.351	19.0	21.8	25.3	35.5
		100	144,000	6.701	68.7	78.8	91.4	128.
		150	216,000	10.052	146.	167.	194.	271.
		200	288,000	13.402	248.	284.	330.	462.
		250	360,000	16.753	375.	430.	499.	699.
		300	432,000	20.103	526.	603.	699.	980.
3	3.068	10	14,400	0.434	0.336	0.385	0.446	0.626
		15	21,600	.651	.711	.816	.946	1.33
		20	28,800	.868	1.21	1.39	1.61	2.26
		25	36,000	1.085	1.83	2.10	2.44	3.41
		50	72,000	2.170	6.61	7.58	8.79	12.3
		100	141,000	4.340	23.9	27.4	31.7	44.5
		200	288,000	8.680	86.1	98.8	115.	161.
		300	432,000	13.020	182.	209.	243.	340.
		400	576,000	17.360	311.	357.	414.	580.
		500	720,000	21.699	470.	539.	625.	876.
3½	3.548	10	14,400	0.325	0.165	0.190	0.220	0.308
		15	21,600	.487	.350	.402	.466	.653
		20	28,800	.649	.597	.684	.794	1.11
		25	36,000	.811	.902	1.03	1.20	1.68
		50	72,000	1.623	3.26	3.73	4.33	6.07
		100	144,000	3.245	11.8	13.5	15.6	21.9
		200	288,000	6.490	42.4	48.7	56.4	79.1
		300	432,000	9.735	89.9	103.	120.	168.
		400	576,000	12.980	153.	176.	204.	286.
		500	720,000	16.225	231.	266.	308.	432.
		600	864,000	19.470	324.	372.	432.	605.
4	4.026	20	28,800	0.504	0.322	0.370	0.429	0.601
		25	36,000	.630	.487	.559	.648	.909
		30	43,200	.756	.683	.784	.909	1.27
		40	57,600	1.008	1.16	1.33	1.55	2.17
		50	72,000	1.260	1.76	2.02	2.34	3.28
		100	144,000	2.520	6.35	7.28	8.45	11.8
		200	288,000	5.040	22.9	26.3	30.5	42.7
		300	432,000	7.561	48.6	55.7	64.6	90.6
		400	576,000	10.081	82.7	94.9	110.	154.
		500	720,000	12.601	125.	143.	166.	233.
		600	864,000	15.121	175.	201.	233.	327.
		800	1,152,000	20.162	299.	343.	397.	557.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
5	5.047	30	43,200	0.481	0.227	0.261	0.302	0.424
		40	57,600	.642	.387	.441	.515	.722
		50	72,000	.802	.585	.671	.779	1.09
		100	144,000	1.604	2.11	2.42	2.81	3.94
		200	288,000	3.208	7.63	8.75	10.1	14.2
		300	432,000	4.812	16.2	18.5	21.5	30.1
		400	576,000	6.416	27.5	31.6	36.6	51.3
		500	720,000	8.020	41.6	47 7	55.3	77.6
		750	1,080,000	12.030	88.2	101.	117.	164.
		1000	1,440,000	16.040	150.	172.	200.	280.

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
6	6.065	50,000	0.0774	0.386	0.122	0.140	0.162	0.227
		60,000	0.928	.463	.171	.196	.227	.318
		80,000	.124	.617	.291	.333	.387	.542
		100,000	.155	.771	.439	.504	.585	.819
		200,000	.309	1.542	1.59	1.82	2.11	2.96
		300,000	.464	2.314	3.36	3.85	4.47	6.27
		400,000	.619	3.085	5.72	6.57	7.62	10.7
		600,000	.928	4.627	12.1	13.9	16.1	22.6
		800,000	1.238	6.170	20.7	23.7	27.5	38.5
		1,000,000	1.547	7.712	31.2	35.8	41.6	58.2
		1,500,000	2.321	11.568	66.2	75.9	88.1	123.
		2,000,000	3.094	15.424	113.	129.	150.	210.
8	7.981	200,000	0.309	0.891	0.416	0.478	0.554	0.777
		300,000	.464	1.336	.882	1.01	1.17	1.65
		400,000	.619	1.781	1.50	1.72	2.00	2.80
		500,000	.774	2.227	2.27	2.61	3.02	4.24
		750,000	1.160	3.340	4.82	5.52	6.41	8.98
		1,000,000	1.547	4.454	8.20	9.41	10.9	15.3
		1,500,000	2.321	6.680	17.4	19.9	23.1	32.4
		2,000,000	3.094	8.907	29.6	34.0	39.4	55.2
		3,000,000	4.642	13.361	62.7	72.0	83.5	117.
10	10.020	300,000	0.464	0.848	0.291	0.334	0.388	0.543
		400,000	.619	1.130	.496	.569	.660	.926
		500,000	.774	1.413	.750	.861	.998	1.40
		750,000	1.160	2.119	1.59	1.82	2.12	2.96
		1,000,000	1.547	2.825	2.71	3.11	3.60	5.05
		2,000,000	3.094	5.651	9.78	11.2	13.0	18.2

Pipe size inches	Inside diameter inches	Discharge in Gallons per 24 hours	Discharge in Cubic feet per second	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f) $c=140$	$c=130$	$c=120$	$c=100$
10	10.020	3,000,000	4.642	8.476	20.7	23.8	27.6	38.6
		4,000,000	6.189	11.302	35.3	40.5	47.0	65.8
		5,000,000	7.736	14.127	53.4	61.2	71.0	99.5
12	12.000	300,000	0.464	0.591	0.121	0.139	0.161	0.226
		400,000	.619	.788	.206	.237	.274	.385
		500,000	.774	.985	.312	.358	.415	.581
		1,000,000	1.547	1.970	1.13	1.29	1.50	2.10
		1,500,000	2.321	2.955	2.38	2.74	3.17	4.45
		2,000,000	3.094	3.940	4.06	4.66	5.40	7.58
		3,000,000	4.642	5.910	8.61	9.87	11.5	16.1
		5,000,000	7.736	9.850	22.2	25.4	29.5	41.3
		7,500,000	11.60	14.775	47.0	53.9	62.5	87.6
		10,000,000	15.47	19.700	80.0	91.8	106.	149.
14 O D	13.250	500,000	0.774	0.808	0.192	0.221	0.256	0.359
		1,000,000	1.547	1.616	.695	.797	.924	1.30
		2,000,000	3.094	3.232	2.51	2.88	3.34	4.68
		3,000,000	4.642	4.847	5.31	6.09	7.07	9.91
		5,000,000	7.736	8.079	13.7	15.7	18.2	25.5
		7,500,000	11.60	12.119	29.0	33.3	38.6	54.1
		10,000,000	15.47	16.158	49.4	56.6	65.7	92.1
		12,500,000	19.34	20.198	74.7	85.6	99.3	139.
16 O D	15.250	750,000	1.160	0.915	0.206	0.236	0.274	0.383
		1,000,000	1.547	1.220	.350	.402	.466	.653
		2,000,000	3.094	2.440	1.26	1.45	1.68	2.36
		3,000,000	4.642	3.659	2.68	3.07	3.56	5.00
		5,000,000	7.736	6.099	6.90	7.91	9.18	12.9
		7,500,000	11.60	9.148	14.6	16.8	19.4	27.3
		10,000,000	15.47	12.198	24.9	28.6	33.1	46.4
		15,000,000	23.21	18.297	52.8	60.5	70.2	98.4
18 O D	17.182	1,000,000	1.547	.961	0.196	0.225	0.261	0.365
		2,000,000	3.094	1.922	.707	.811	.941	1.32
		3,000,000	4.642	2.883	1.50	1.72	1.99	2.79
		5,000,000	7.736	4.805	3.86	4.43	5.13	7.20
		7,500,000	11.60	7.207	8.18	9.38	10.9	15.2
		10,000,000	15.47	9.609	13.9	16.0	18.5	26.0
		15,000,000	23.21	14.414	29.5	33.9	39.3	55.0
		20,000,000	30.94	19.218	50.3	57.7	66.9	93.8
20 O D	19.182	1,000,000	1.547	0.771	0.115	0.131	0.152	0.214
		2,000,000	3.094	1.542	.414	.475	.550	.771
		3,000,000	4.642	2.313	.876	1.01	1.17	1.63
		5,000,000	7.736	3.855	2.26	2.59	3.00	4.21
		7,500,000	11.60	5.782	4.78	5.49	6.36	8.92
		10,000,000	15.47	7.710	8.15	9.35	10.8	15.2
		15,000,000	23.21	11.565	17.3	19.8	23.0	32.2
		20,000,000	30.94	15.419	29.4	33.7	39.1	54.8

Table 16

Loss of Head in Pipe by Friction for Large Diameter Pipe Listed by I. D. Sizes, Calculated by Hazen-Williams Formula

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
22	1.8333	1	1.547	0.586	0.059	0.067	0.078	0.110
		2.5	3.868	1.465	.321	.368	.427	.598
		5	7.736	2.931	1.16	1.33	1.54	2.16
		7.5	11.60	4.396	2.45	2.81	3.26	4.57
		10	15.47	5.861	4.18	4.79	5.56	7.79
		15	23.21	8.792	8.86	10.2	11.8	16.5
		20	30.94	11.722	15.1	17.3	20.1	28.1
		25	38.68	14.653	22.8	26.2	30.3	42.5
24	2.0000	2	3.094	0.985	0.139	0.159	0.185	0.259
		5	7.736	2.462	.758	.869	1.01	1.41
		7.5	11.60	3.694	1.61	1.84	2.14	2.99
		10	15.47	4.925	2.74	3.14	3.64	5.10
		15	23.21	7.387	5.80	6.65	7.71	10.8
		20	30.94	9.850	9.87	11.3	13.1	18.4
		25	38.68	12.312	14.9	17.1	19.9	27.8
		30	46.42	14.775	20.9	24.0	27.8	39.0
26	2.1667	2	3.094	0.839	0.094	0.108	0.125	0.175
		5	7.736	2.098	.513	.589	.683	.957
		7.5	11.60	3.147	1.09	1.25	1.45	2.03
		10	15.47	4.196	1.85	2.12	2.46	3.45
		15	23.21	6.295	3.93	4.50	5.22	7.32
		20	30.94	8.393	6.69	7.67	8.90	12.5
		25	38.68	10.491	10.1	11.6	13.4	18.8
		30	46.42	12.589	14.2	16.3	18.8	26.4
28	2.3333	2	3.094	0.724	0.066	0.075	0.087	0.122
		5	7.736	1.809	.358	.410	.476	.667
		7.5	11.60	2.714	.758	.869	1.01	1.41
		10	15.47	3.618	1.29	1.48	1.72	2.41
		15	23.21	5.428	2.74	3.14	3.64	5.10
		20	30.94	7.237	4.66	5.35	6.20	8.69
		25	38.68	9.046	7.05	8.08	9.37	13.1
		30	46.42	10.855	9.88	11.3	13.1	18.4
30	2.5000	5	7.736	1.576	0.256	0.293	0.340	0.477
		10	15.47	3.152	.923	1.06	1.23	1.72
		15	23.21	4.728	1.96	2.24	2.60	3.65
		20	30.94	6.304	3.33	3.82	4.43	6.21
		25	38.68	7.880	5.03	5.78	6.70	9.39
		30	46.42	9.456	7.06	8.10	9.39	13.2
		35	54.15	11.032	9.39	10.8	12.5	17.5
		40	61.89	12.608	12.0	13.8	16.0	22.4
36	3.0000	5	7.736	1.094	0.105	0.121	0.140	0.196
		10	15.47	2.189	.380	.436	.505	.708
		15	23.21	3.283	.804	.923	1.07	1.50
		20	30.94	4.378	1.37	1.57	1.82	2.56
		30	46.42	6.567	2.90	3.33	3.86	5.41
		40	61.89	8.756	4.95	5.67	6.58	9.22
		50	77.36	10.944	7.48	8.58	9.95	13.9
		60	92.83	13.133	10.5	12.0	13.9	19.5

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Million gallons per 24 hours	Cubic feet per second		c=140	c=130	c=120	c=100
42	3.50	5	7.736	0.804	0.050	0.057	0.066	0.093
		10	15.47	1.608	.179	.206	.238	.334
		15	23.21	2.412	.380	.436	.505	.708
		20	30.94	3.216	.647	.742	.861	1.21
		30	46.42	4.824	1.37	1.57	1.82	2.56
		40	61.89	6.433	2.34	2.68	3.11	4.35
		50	77.36	8.041	3.53	4.05	4.70	6.58
		75	116.0	12.061	7.48	8.58	9.95	13.9
48	4.00	5	7.736	0.616	0.026	0.030	0.034	0.048
		10	15.47	1.231	.094	.107	.124	.174
		20	30.94	2.462	.338	.387	.449	.630
		30	46.42	3.694	.715	.821	.952	1.33
		40	61.89	4.925	1.22	1.40	1.62	2.27
		50	77.36	6.156	1.84	2.11	2.45	3.44
		75	116.0	9.234	3.90	4.48	5.19	7.28
		100	154.7	12.312	6.65	7.63	8.85	12.4
54	4.50	10	15.47	0.973	0.053	0.060	0.070	0.098
		20	30.94	1.946	.190	.218	.253	.355
		30	46.42	2.919	.403	.462	.536	.752
		40	61.89	3.891	.687	.788	.913	1.28
		50	77.36	4.864	1.04	1.19	1.38	1.94
		75	116.0	7.296	2.20	2.52	2.93	4.10
		100	154.7	9.728	3.75	4.30	4.98	6.99
		125	193.4	12.160	5.66	6.50	7.54	10.6
60	5.00	10	15.47	0.788	0.032	0.036	0.042	0.059
		20	30.94	1.576	.114	.131	.151	.212
		30	46.42	2.364	.241	.277	.321	.450
		40	61.89	3.152	.411	.471	.547	.766
		50	77.36	3.940	.621	.713	.827	1.16
		75	116.0	5.910	1.32	1.51	1.75	2.45
		100	154.7	7.880	2.24	2.57	2.98	4.18
		125	193.4	9.850	3.39	3.89	4.51	6.32
66	5.50	10	15.47	0.651	0.020	0.023	0.026	0.037
		20	30.94	1.302	.072	.082	.095	.133
		30	46.42	1.954	.152	.174	.202	.283
		50	77.36	3.256	.391	.448	.520	.728
		75	116.0	4.884	.828	.949	1.10	1.54
		100	154.7	6.512	1.41	1.62	1.88	2.63
		125	193.4	8.140	2.13	2.44	2.84	3.97
		150	232.1	9.769	2.99	3.43	3.97	5.57
72	6.00	10	15.47	0.547	0.013	0.015	0.017	0.024
		25	38.68	1.368	.071	.081	.094	.132
		50	77.36	2.736	.256	.293	.340	.477
		75	116.0	4.104	.542	.621	.721	1.01
		100	154.7	5.472	.923	1.06	1.23	1.72
		125	193.4	6.840	1.40	1.60	1.86	2.60
		150	232.1	8.208	1.96	2.24	2.60	3.65
		175	270.8	9.576	2.60	2.98	3.46	4.85

Pipe inside diameter		Discharge in		Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe (h_f)			
Inches	Feet (D)	Cubic feet per second	Million gallons per 24 hours		c=140	c=130	c=120	c=100
78	6.50	25	16.16	0.753	0.021	0.025	0.028	0.040
		50	32.32	1.507	.077	.089	.103	.144
		75	48.47	2.260	.163	.188	.217	.305
		100	64.63	3.014	.278	.319	.371	.519
		150	96.95	4.520	.590	.677	.785	1.10
		200	129.3	6.027	1.01	1.15	1.34	1.87
		250	161.6	7.534	1.52	1.74	2.02	2.83
		300	193.9	9.041	2.13	2.44	2.83	3.97
84	7.00	25	16.16	0.650	0.015	0.017	0.020	0.028
		50	32.32	1.299	.054	.062	.072	.100
		75	48.47	1.949	.114	.131	.152	.212
		100	64.63	2.598	.194	.223	.258	.362
		150	96.95	3.898	.411	.472	.547	.767
		200	129.3	5.197	.701	.804	.932	1.31
		250	161.6	6.496	1.06	1.22	1.41	1.98
		300	193.9	7.795	1.48	1.70	1.98	2.77
90	7.50	25	16.16	0.566	0.011	0.012	0.014	0.020
		50	32.32	1.132	.038	.044	.051	.072
		75	48.47	1.698	.081	.093	.108	.152
		100	64.63	2.264	.139	.159	.185	.259
		150	96.95	3.395	.294	.337	.391	.548
		200	129.3	4.527	.501	.574	.666	.934
		300	193.9	6.791	1.06	1.22	1.41	1.98
		400	258.5	9.054	1.81	2.07	2.40	3.37
96	8.00	25	16.16	0.497	0.008	0.009	0.010	0.014
		50	32.32	0.995	.028	.032	.037	.052
		100	64.63	1.989	.101	.116	.135	.189
		150	96.95	2.984	.215	.246	.286	.400
		200	129.3	3.979	.366	.419	.486	.682
		300	193.9	5.968	.775	.889	1.03	1.44
		400	258.5	7.958	1.32	1.51	1.76	2.46
		500	323.2	9.947	2.00	2.29	2.65	3.72

The Scobey Formula

Fred C. Scobey,* Senior Irrigation Engineer of the Division of Agricultural Engineering, U. S. Department of Agriculture, offers the following formulas which he says "include viscosity influence for a temperature of 15° C. (59° F.) and differentiate between various types and classes of sheet and plate metal pipe by means of coefficients, which are themselves constant throughout the whole range of sizes and velocities for a given class of pipe":

$$hf = \frac{K_s v^{1.9}}{D^{1.1}}$$

$$v = \frac{hf^{.0538} D^{0.58}}{K_s{}^{.0538}}$$

where hf = Loss of head in feet due to friction per 1000 feet of pipe.
D = Mean inside diameter of pipe in feet.
v = Mean velocity of the water in feet per second.
K_s = General coefficient. (K'_s is this value for new pipe.)

Scobey limited his study to pipe of nominal size, four inch and larger, and assumed that the interior of all pipe would be chemically protected with a coating which would form the true interior surface, at least during the first years of the life of the conduit.

He divides sheet and plate metal pipe into three major classes:

Class 1—"Full-riveted" pipe, having both longitudinal and girth seams held by one or more lines of rivets with projecting

*United States Department of Agriculture Technical Bulletin No. 150 "The Flow of Water in Riveted Steel and Analogous Pipes" (1930).

Table 17

Loss of Head in Pipe by Friction for National Duroline Pipe* Calculated by the Hazen-Williams Formula

Pipe size, inches	Average inside diameter, inches	Discharge in Gallons per minute	Discharge in Gallons per 24 hours	Velocity in feet per second (v)	Loss of head in feet per 1000 feet of pipe ($c = 148$) (hr)
½	0.484	1	1,440	1.74	35.0
		2	2,880	3.48	126.0
		3	4,320	5.23	265.0
		4	5,760	6.97	455.0
		5	7,200	8.72	685.0
		6	8,640	10.46	970.0
		8	11,520	13.95	1650.0
		10	14,400	17.44	2500.0
¾	0.686	2	2,880	1.73	22.8
		3	4,320	2.60	48.0
		4	5,760	3.47	82.0
		5	7,200	4.34	124.0
		6	8,640	5.21	173.0
		8	11,520	6.94	295.0
		10	14,400	8.68	443.0
		15	21,600	13.02	946.0
		20	28,800	17.36	1590.0
1	0.896	3	4,320	1.52	13.2
		4	5,760	2.03	22.2
		5	7,200	2.54	34.5
		6	8,640	3.05	47.5
		8	11,520	4.07	81.0
		10	14,400	5.08	120.0
		12	17,280	6.10	170.0
		14	20,160	7.12	225.0
		16	23,040	8.14	290.0
		20	28,800	10.16	432.0
		25	36,000	12.70	630.0
		30	43,200	15.24	925.0
1¼	1.175	4	5,760	1.18	5.8
		5	7,200	1.47	9.0
		6	8,640	1.77	12.6
		7	10,080	2.07	16.7
		8	11,520	2.36	21.5
		10	14,400	2.95	32.5
		12	17,280	3.55	45.5
		14	20,160	4.14	59.0
		16	23,040	4.73	77.0
		18	25,920	5.32	96.0
1¼	1.175	20	28,800	5.91	116.0
		25	36,000	7.39	175.0
		30	43,200	8.87	245.0
		40	57,600	11.80	420.0
		60	86,400	17.70	880.0
1½	1.405	4	5,760	0.82	2.60
		5	7,200	1.03	3.95
		6	8,640	1.24	5.28
		7	10,080	1.44	7.3
		8	11,520	1.65	9.4
		9	12,960	1.86	11.6
		10	14,400	2.06	14.2
		12	17,280	2.48	19.8
		14	20,160	2.89	26.4
		16	23,040	3.31	34.5
		18	25,920	3.72	42.0
		20	28,800	4.13	51.0
		22	31,680	4.55	61.0
		24	34,560	4.96	72.0
		26	37,440	5.38	83.0
		28	40,320	5.79	95.0
		30	43,200	6.20	108.0
		35	50,400	7.24	135.0
		40	57,600	8.27	176.0
		50	72,000	10.34	266.0
		75	108,000	15.51	562.0
		100	144,000	20.69	960.0
2	1.780	6	8,640	0.77	1.66
		8	11,520	1.03	2.82
		10	14,400	1.28	4.30
		12	17,280	1.54	6.0
		14	20,160	1.80	8.0
		16	23,040	2.06	10.2
2	1.780	18	25,920	2.32	12.7
		20	28,800	2.57	15.5
		25	36,000	3.22	23.2
		30	43,200	3.86	33.0
		35	50,400	4.51	44.0
		40	57,600	5.15	56.0
		45	64,800	5.80	77.0
		50	72,000	6.44	84.0
		55	79,200	7.09	100.0
		60	86,400	7.73	117.0
		65	93,600	8.37	135.0
		70	100,800	9.02	157.0
		75	108,000	9.66	177.0
		100	144,000	12.89	302.0
		150	216,000	19.33	570.0
2½	2.182	8	11,250	0.63	1.05
		10	14,400	.85	1.58
		12	17,280	1.02	2.25
3	2.725	10	14,400	0.55	0.54
		15	21,600	.82	1.15
		20	28,800	1.10	1.95
		25	36,000	1.37	2.95
		50	72,000	2.75	10.6
		80	115,200	4.40	25.3
		100	144,000	5.50	38.5
		160	230,400	8.80	90.0
		200	288,000	11.00	136.0
		300	432,000	16.50	290.0
		400	576,000	22.00	500.0
		500	720,000	27.50	750.0
3½	3.205	10	14,400	0.39	0.24
		15	21,600	.59	.52
		20	28,800	.79	.88
		25	36,000	.99	1.34
		50	72,000	1.98	4.8
4	3.620	20	28,800	0.62	0.49
		25	36,000	.77	.74
		30	43,200	.93	1.04
		50	72,000	1.55	2.68
		80	115,200	2.49	6.4
		100	144,000	3.11	9.7
		160	230,400	4.98	23.4
		200	288,000	6.23	35.0
		300	432,000	9.35	72.2
		400	576,000	12.46	124.0
		500	720,000	15.58	187.0
5	4.548	30	43,200	0.59	0.34
		40	57,600	.79	.58
		50	72,000	.98	.87
		80	115,200	1.58	2.10
		100	144,000	1.97	3.15
		160	230,400	3.16	7.7
		200	288,000	3.95	11.5
		300	432,000	5.92	24.2
		400	576,000	7.90	41.2
		500	720,000	9.87	61.8
		750	1,080,000	14.81	131.0
6	5.440	50,000	.0774	0.47	0.20
		60,000	.0928	.57	.26
		80,000	.1238	.76	.44
		100,000	.1547	.95	.66
		140,000	.2166	1.34	1.25
		200,000	.3094	1.91	3.42
		300,000	.4642	2.87	5.2
		400,000	.619	3.83	8.7
		500,000	.774	4.79	13.2
		600,000	.928	5.75	18.5
		800,000	1.238	7.67	31.5
		1,000,000	1.547	9.58	48.0
		1,500,000	2.321	14.37	100.0
		2,000,000	3.094	19.17	170.0
8	7.446	200,000	.3094	1.02	0.53
		300,000	.4642	1.53	1.12
		360,000	.557	1.84	1.57
		400,000	.619	2.04	1.92
		500,000	.774	2.55	2.88
		600,000	.928	3.06	4.05
		700,000	1.083	3.58	5.4
		800,000	1.238	4.09	6.9
		900,000	1.392	4.60	8.6
		1,000,000	1.547	5.11	10.5
		1,200,000	1.857	6.13	14.6
3	7.356	200,000	.3094	1.04	0.56
		300,000	.4642	1.57	1.18
		400,000	.619	2.09	2.00
		500,000	.774	2.62	3.05
		600,000	.928	3.14	4.30
		700,000	1.083	3.66	5.7
		800,000	1.238	4.19	7.3
		1,000,000	1.547	5.24	11.2
		1,500,000	2.321	7.86	23.8
		2,000,000	3.094	10.48	40.0
		3,000,000	4.642	15.72	84.0
10	9.443	300,000	.4642	0.95	0.35
		400,000	.619	1.27	.60
		500,000	.774	1.59	.90
		600,000	.928	1.90	1.26
		750,000	1.160	2.38	1.92
		1,000,000	1.547	3.18	3.25
		1,500,000	2.321	4.77	6.9
		2,000,000	3.094	6.36	11.8
		3,000,000	4.642	9.54	25.0
		4,000,000	6.188	12.72	42.5

*Pipe lined with a highly resistant cement-base composition lining.—Ed.

heads. From the capacity standpoint, pipe with countersunk rivet heads on the interior belong in *Class* 3.

Class 2—"Girth-riveted" pipe, having no retarding rivet heads in the longitudinal seams, but having the same girth seams as full-riveted pipe.

Class 3—"Continuous-interior" pipe, having the interior surface unmarred by plate offsets or by projecting rivet heads in either longitudinal or girth seams. Not necessarily described as "smooth."

For these classes Scobey suggests the following coefficients for new pipe:

Class 1*a*, $K'_s = 0.38$ for new sheet metal pipe up to three-sixteenths of an inch thick.

Class 1*b*, $K'_s = 0.44$ for new plate metal pipe on three-sixteenths to seven-sixteenths of an inch thick, with either taper or cylinder joints.

Class 1*c*, $K'_s = 0.48$ for new plate metal pipe from one-half inch up, with either taper or cylinder joints, and for plate from one-fourth to seven-sixteenths of an inch thick when butt-jointed.

Class 1*d*, $K'_s = 0.52$ for new butt-strap pipe of plate from one-half inch up.

Class 2*d*, $K'_s = 0.34$ for new girth-riveted pipe. This includes all sheet and plate metal pipe with continuous seamed lognitudinal joints but with girth joints, particularly field joints, made with the usual rivet heads inside the pipe.

Class 3, $K'_s = 0.32$ for new continuous-interior pipe. This class comprises all type of sheet and plate metal pipe that offer a practically uniform interior surface of relative smoothness. "Continuous-interior" is offered as descriptive of an interior surface unbroken by rivet heads or appreciable shell-thickness offsets. Use of the apparently obvious synonym "smooth" has purposely been avoided, as this description might hold only while the pipe is new.

NOTE: Although Scobey confines his paper to the discussion of sheet and plate metal pipe, *Classes* 2 and 3 also apply to seamless pipe as well as to lap-weld, hammer-weld, and electric-weld pipe.

It should be noted that the coefficients (K'_s) given above

are for new pipe. Concerning the deterioration of carrying capacity with age, Scobey states:

"It has long been appreciated that all metal pipe deteriorates in carrying capacity; the rate of decrease being dependent on the efficiency of the pipe coating, the composition and treatment of the pipe material, and the activity of the water conveyed in the pipe. Filtered and treated water causes less deterioration than raw water. Long lines deteriorate more rapidly at the upper ends than at the lower ends. "So far as available data indicate, the increase in the value of K_s with age, is expressed by the formula:

$$K_s = K'_s e^{0.015t}$$

where e = Base of Naperian logarithms (2.7183).
t = Age of pipe in years.
When t is zero, then K_s becomes K'_s."

[NOTE: Tables showing various values of K_s and corresponding losses of head at various velocities and also values of $v^{1.9}$ have had to be omitted. For a copy of these address National Tube Co., Pittsburgh, Pa., asking for Technical Bulletin No. 21. —Ed.]

Fig. 36, which was taken from United States Department of Agriculture Technical Bulletin No. 150, will be found useful in making estimates and preliminary studies. It gives the relation between discharge, pipe diameter, velocity, and loss of head for various values of the coefficient K_s. Values of K_s for ages of 0 to 50 years corresponding to various values of K'_s are also given.

The lower age diagram on the chart is based on the formula $K_s = K'_s e^{0.015t}$ and is to be used for aggressive waters. The upper age diagram is based on the formula $K_s = K'_s e^{0.01t}$ and is intended for use where the waters are known to be non-aggressive.

The following example will illustrate the method of using this chart:

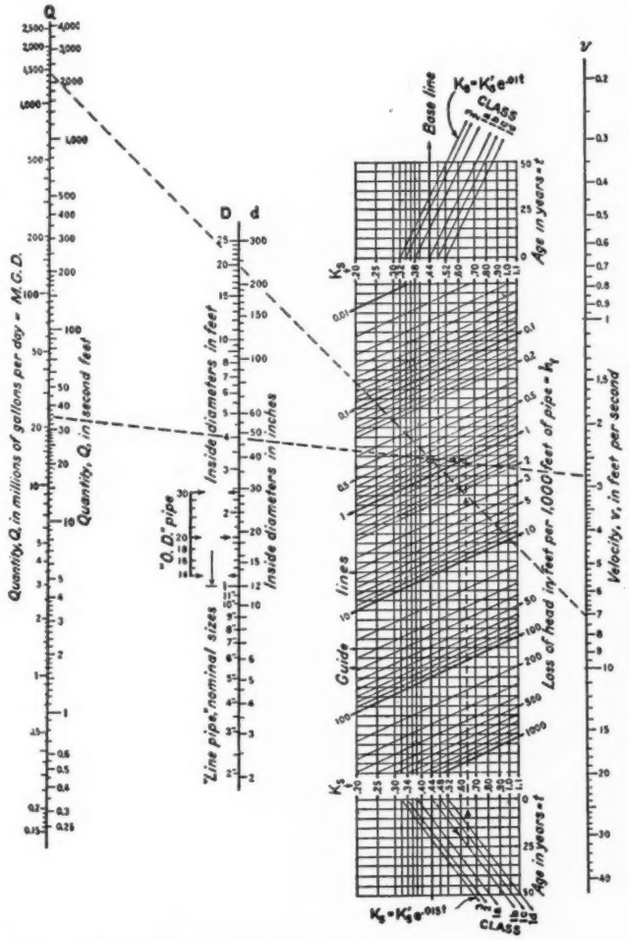

Q
Quantity, Q, in millions of gallons per day = M.G.D.
Quantity, Q, in second feet
D d
"O.D." pipe
"Line pipe," nominal sizes
Inside diameters in feet
Inside diameters in inches
Guide lines
Base line
Age in years = t
Loss of head in feet per 1,000 feet of pipe = K_s
Velocity, v, in feet per second
v

Fig. 36 — Chart Showing Relation Between Discharge Pipe Diameter, Velocity, and Loss of Head for Various Values of the Coefficient K_s and K_{s1} in Scobey Formula

Table 21

Special Losses of Head in Terms of $v^2/2g$ (From Hydraulics, by Ernest W. Schoder and Francis M. Dawson—Second Edition, 1934, with Modifications)

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Entrance	
Square-edged entry. Upstream end of pipe perpendicular to, and flush with inside face of reservoir wall	0.50
Projecting pipe at entry or re-entrant pipe end	1.00
Well-rounded entry	0.02 to 0.05
Curves and Fittings	
Easy curves or bends of very large radius, and smooth inside, of same inside diameter throughout as the pipe line. Excess loss over same length of straight pipe	0.05 to 0.15
90-degree curves, fairly smooth, same inside diameter as pipe; Radius of center line = diameter of pipe	0.50
Radius of center line = 2 to 8 times diameter of pipe	0.25
90-degree common screw end pipe elbows, short turn, inside larger than pipe	0.75
Tees, common screw end, full-size branch, flow deviated 90 degrees	1.50
Square elbow (intersection of two cylinders, corner not rounded at outside or inside of curve.)	1.25
Obtuse-angled elbows, (deflection of pipe less than 90 degrees); multiply values for square elbow or 90-degree curve by $\left(\frac{\text{deflection, degrees}}{90 \text{ degrees}}\right)^2$	
Water Meters (Subject to much variation)	
Disk or "wobble-disk" type	3.4 to 10
Rotary type (star or cog-wheel-shaped disk as piston)	10
Reciprocating piston type (like a piston pump)	15
Turbine-wheel type (double flow, balanced)	5 to 7.5
Diaphragm and Orifice Meters	
Diaphragm of thin material across pipe, with concentric hole, or an inside projecting washer or gasket, or a "burr", due to cutting pipe with a wheel cutter: Diameter of hole = 0.91 × diameter of pipe	0.34
Diameter of hole = 0.80 × diameter of pipe	1.88
(Note that $v^2/2g$ in this particular case refers to pipe, not to the area of opening, nor to the contracted stream through opening.)	
Nozzles	
Nozzles: when the coefficient of velocity and discharge ranges from 0.99 to 0.975, the loss of head ranges from	0.02 to 0.05 (Where v is the velocity of the issuing jet)

*Note: Except where otherwise noted, v is the mean velocity in the pipe.

Assume that it is desired to know what conditions will prevail in a pipe line constructed of full-riveted pipe (*Class* 1*b*) after carrying aggressive waters for a period of 25 years.

From page 45 the coefficient K_s for new pipe of *Class* 1*b* is found to be 0.44. On the lower age diagram follow the diagonal line representing $K_s = 0.44$ (at 0 age) until it intersects the horizontal line representing an age of 25 years. From this point of intersection proceed vertically on the dashed line (which represents $K_s = 0.64$) until it intersects the slope line of 1 foot per 1000 feet of pipe. From this point follow the guide lines to the vertical base line. Using this point (marked on the chart by a circle) as a pivot, a straight edge will give simultaneous values of discharge (Q) diameter (D or d) and velocity (v). This is illustrated by dashed lines for 20 feet and 4 feet inside diameter pipe. The dashed line through the pivot point and the point representing pipe of 20 feet inside diameter shows that a discharge of 2250 cubic feet per second and a velocity of 7.2 feet per second can be expected. The other dashed line through the pivot point and through the point representing pipe 4 feet inside diameter indicates a discharge of 36 cubic feet per second and a velocity of 2.8 feet per second.

Special Losses of Head

Curves, elbows, tees, meters, enlargements, contractions, etc., in a pipe line cause losses of head, which, if of consequence, must be allowed for in addition to the loss of head ordinarily encountered in straight pipe of uniform cross section.

Special losses may be expressed as equivalent lengths of straight pipe which would cause the same loss of head, or as decimals or multiples of $v^2/2g$, where v is the mean velocity in the pipe. For any particular special fittings, experiments show that the loss of head is not in all cases a constant fraction of

Table 21—Concluded

Special Losses of Head in Terms of $v^2/2g$

Nature of special resistance	Loss of head as decimal or multiple of $v^2/2g$*
Venturi Meter Tubes	
Venturi meter tubes: the loss of head occurs mostly in and downstreamwards from the divergence, the loss between upstream end and throat being only 0.03 to 0.06$\times v^2/2g$, where v is the throat velocity. The total loss through the meter is:	
For total angle of divergence $= \pm 5$ degrees	$\frac{1}{7}$ to $\frac{1}{10}$ } Where v is the throat velocity
For total angle of divergence $= \pm 15$ degrees	$\frac{1}{3}$ to $\frac{1}{6}$ }
(The lower values go with large throats, and the larger values with small throats whose diameter is from ⅓ to ½ the diameter of the pipe.)	
Sudden Enlargement	
Sudden enlargement, from a small pipe ending abruptly where a larger pipe begins, is found to involve loss of head fairly close in accordance with Borda's Formula which is: Loss of head $= \frac{(v_1 - v_2)^2}{2g}$ (Note that this is not the difference of the velocity heads, but is the head corresponding to the difference of the velocities.) The above-stated formula may be written: Loss of head $= \left(1 - \frac{A_1}{A_2}\right)^2 \frac{v_1^2}{2g}$, or for a circular or square pipe: Loss of head $= \left[1 - \left(\frac{d_1}{d_2}\right)^2\right]^2 \times \frac{v_1^2}{2g}$ where A_1, v_1 and d_1 refer to the smaller upstream pipe, while the subscript 2 refers to the larger downstream pipe.	
Sudden Square-Edged Reductions	
Sudden square-edged reductions in pipes. When the sudden reduction of pipe is very large, say $d_2/d_1 = 0.1$, the loss of head is practically as given for square-edged entry, i.e., loss of head $= 0.40\, v_2^2/2g$. For smaller reductions the value of K is smaller, but the experimental data of Weisbach (1855) and Brightmore (1907) do not agree. For ratios $d_2/d_1 =$ 0.5, 0.75, and 0.9 the value K is about 0.33, 0.20 and 0.08, respectively. In this case the subscript 2 refers to the smaller downstream pipe, and K is the factor which, multiplied by $v_2^2/2g$, gives the loss of head.	

*Note: Except where otherwise noted, the v is mean velocity in the pipe.

$v^2/2g$, but that the fraction varies somewhat with the velocity. For most practical purposes, however, the values given in 21 may be relied on as safe average values.

Water Hammer

When a valve in a water line is closed while the water is flowing, the velocity of the water upstream from the valve is reduced and a dynamic pressure is exerted in addition to the normal static pressure. This dynamic pressure, commonly called "water hammer," is the result of the transformation of the kinetic energy of the moving mass of water into pressure energy which expends itself (unless relief devices are provided) by compressing the water and stretching the pipe walls. When a valve is closed suddenly, the magnitude of the dynamic pressure produced is frequently much greater than the static pressure on the line, and may cause fracture of the pipe or fittings.

Starting at the suddenly-closed valve, a wave of increased pressure is transmitted back through the pipe with constant velocity and intensity. When the pressure wave has traveled upstream to the end of the pipe, where there is a reservoir or large main, the elasticity of the compounded water and of the expanded pipe reverse the flow and a wave of normal pressure travels downstream, the flow being progressively reversed as the water expands.

If the water were incompressible and the pipe inelastic, the instantaneous closure of the valve would create an infinite pressure. Since it is impossible to close a valve instantaneously, it is apparent that a series of pressure waves is created, causing an increased pressure at the valve. If the valve is completely closed before the first pressure wave has time to return to the valves as a wave of low pressure, the pressure increases continually up to the time of complete closure and the resulting pressure is just the same as if the valve had been instantaneously closed. The velocity of the pressure wave depends upon the ratio of wall-thickness to inside pipe diameter and on the modulus of elasticity of the water and of the pipe material according to the formula:

$$S = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

The head due to water hammer in excess of normal static head is proportional to the destroyed velocity and to the velocity of the pressure wave along the pipe. Since the intensity of the excess head depends upon the destroyed velocity, the same excess pressure is produced by suddenly reducing the velocity from 6 to 3 feet per second, as by entirely stopping a velocity of 3 feet per second. The excess head due to water hammer is given by the formula:

$$h = \frac{12\, v}{g\sqrt{\frac{w}{g}\left(\frac{1}{E_w} + \frac{d}{E_p t}\right)}}$$

where S = Velocity of pressure wave along pipe in feet per second.
w = Weight of water in pounds per cubic foot.
h = Head due to water hammer (in excess of static head).
g = Acceleration of gravity.
t = Wall-thickness of pipe in inches.
d = Inside diameter of pipe in inches.
E_p = Modulus of elasticity of pipe material in pounds per square inch.
E_w = Modulus of elasticity of water in pounds per square inch.
v = Destroyed velocity in feet per second.

By inserting values for g, w, E_w and E_p the two formulas may be simplified. Thus, if
$g = 32.174$ feet per second per second.
$w = 62.4096$ pounds per cubic foot (at 50° F.)
$E_w = 300{,}000$ pounds per square inch.
$E_p = 29{,}000{,}000$ pounds per square inch (for steel pipe)
the formulas reduce to:

$$S = \frac{4720}{\sqrt{1 + .0103\frac{d}{t}}}$$

$$h = \frac{147\, v}{\sqrt{1 + .0103\frac{d}{t}}}$$

If the flow is not checked rapidly, so that the wave from the first movement of the valve has time to travel upstream to the end and back again several times while the valve closing is in progress, the excess pressure is greatly reduced. Therefore, it is advisable to use slow closing valves or to provide air chambers or surge tanks in the line to absorb the shock due to water hammer.

Measurement of Flowing Water

Pitot Tubes

Pitot tubes are used to measure the velocity of flowing water. Such a tube consists essentially of a vertical tube, the lower end of which is bent at 90° so that its open end is directed against the current. The velocity of the flowing water causes the water to rise in the vertical leg of the pitot tube a distance above the free surface of the stream equal to the velocity head.

When a pitot tube is inserted into a pipe carrying water under pressure, the water will rise in the vertical leg of the tube a distance equal to the sum of the pressure head and the velocity head at the point where the tube is inserted. If a piezometer tube is tapped into the wall of the pipe at substantially the same point, the water will rise in this tube a distance equal to the pressure head at that point. The difference in the levels of the water in the two tubes will therefore be equal to the velocity head in the pipe at the point where the tubes are inserted. Fig. 37 shows such an arrangement. The height of the water in the pitot tube is equal to the sum of the pressure head, h_p, and the velocity head, h_v. The height of the water in the piezometer tube is equal to the pressure head, h_p. The

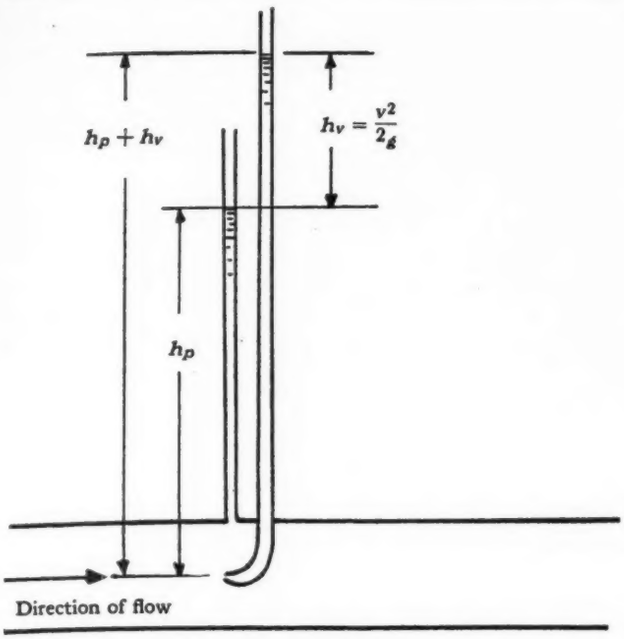


Fig. 37—Pitot Tube

difference in the height of the water in the two tubes is therefore equal to the velocity head, h_v.

Mercury columns or manometers may be used, instead of the water column, to determine the pressures.

In order to determine the discharge by use of a pitot tube, the cross section of the stream or pipe must be divided into one or more known areas, the velocity for each found, and hence the mean velocity of the entire cross section. The discharge is then found by multiplying the cross-sectional area by the mean velocity. In a straight length of pipe which extends upstream about 50 diameters from place of measurement without tees, valves, etc., the distribution of velocities is normal. Where normal distribution of velocities prevails, the ratio of mean velocity to center velocity (called the pipe coefficient) averages about 0.83.

Venturi Meters

The Venturi meter was invented by Clemens Herschel and was named by him for the inventor of the principle involved. It may be used to measure the discharge of water or other fluids contained in pipes which run full and under positive pressure.

The Venturi tube consists of a converging cone of steep taper, a diverging cone of more gradual taper, and a short cylindrical section called the throat, which connects the two cones at their smallest diameters. The essential parts of a Venturi meter are shown in Fig. 38. In this figure h_1 represents the pressure head in the pipe upstream for the Venturi meter, h_2 the pressure head at the throat, and h_3 the pressure head in the pipe downstream from the Venturi meter. The difference between h_1 and h_3 is hf and is the loss of head due to friction in the Venturi tube. The loss of head in a Venturi tube is usually quite small (see Table 21). Where the recovery of pressure is not important the converging cone may be very short or may even be omitted, forming a Venturi nozzle.

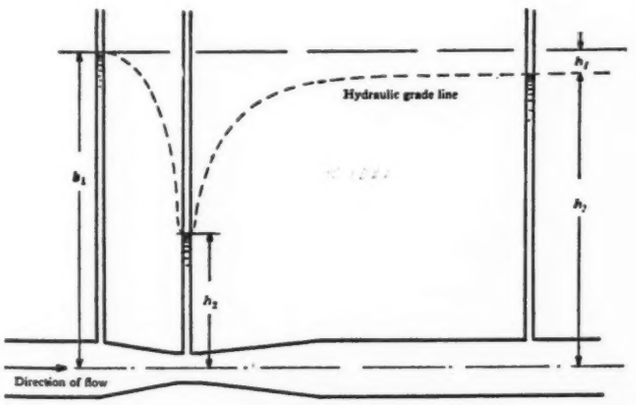


Fig. 38—Venturi Meter

Since the quantity of water flowing past any cross section of the tube is the same at any instant, the velocity at the small cross section of the throat will be greater than in the large cross section of the pipe upstream from the Venturi tube.

This greater velocity in the throat is obtained at the expense of the pressure head, so that h_2 is less than h_1. The dotted line in the figure represents the approximate hydraulic grade line and indicates the loss and recovery of pressure from h_1 to h_2.

The relation between the flow through a Venturi tube and the difference in pressure between the inlet and throat is given by the formula:

$$Q = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_v A_2 \sqrt{\frac{2ghd}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Inside diameter of throat of Venturi tube in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of inside of throat of tube in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_v = Discharge coefficient of Venturi tube which varies from about 0.95 to 0.995.

The pressure differences ($h_1 - h_2$) may be measured by a simple glass U-tube containing mercury. Commercial Venturi tubes are usually provided with two annular chambers connected by vents with the inlet and throat, respectively, to obtain correct average pressures at these points. Various types of indicating, recording and integrating meters may be obtained for use with commercial Venturi tubes.

Pipe Orifices

Orifices in diaphragms inserted between pairs of flanges in straight portions of pipe lines have been found to be reliable measuring devices. The diaphragms are usually of thin noncorrodible metal and the orifices are accurately machined to size and beveled on the downstream side to keep the working edge thin.

Fig. 39 shows the essential parts of such a device. Two piezometer tubes are attached to the line, one at a distance of

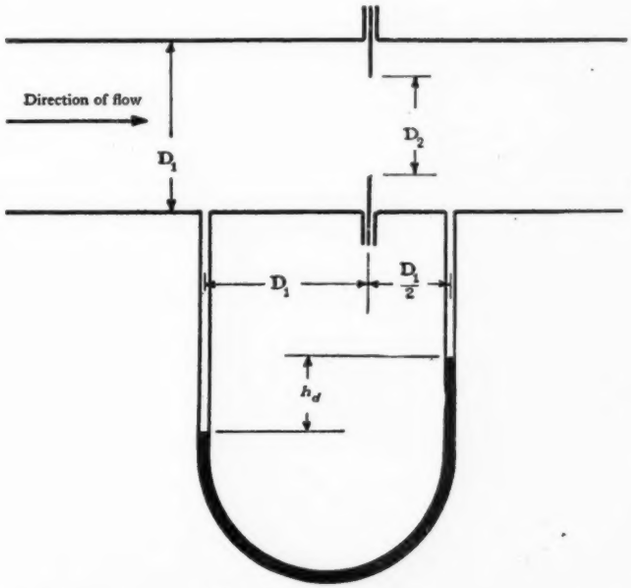


Fig. 39—Pipe Orifice

one pipe diameter upstream and the other one-half pipe diameter downstream from the plate. Either a differential gage, as shown in the figure, or open water columns may be used, depending upon the pressure. The rate of flow is a function of the differential pressure as indicated by the formula:

$$Q = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{A_2}{A_1}\right)^2}} = C_o A_2 \sqrt{\frac{2gh_d}{1-\left(\frac{D_2}{D_1}\right)^4}}$$

where Q = Discharge in cubic feet per second.
D_1 = Inside diameter of pipe in feet.
D_2 = Diameter of orifice in feet.
A_1 = Cross-sectional area of inside of pipe in square feet.
A_2 = Cross-sectional area of orifice in square feet.
g = Acceleration of gravity = 32.174 feet per second per second.
h_d = Differential head in feet of water = $h_1 - h_2$.
C_o = Discharge coefficient = about 0.606 for D_2/D_1 from 0.10 to 0.75.

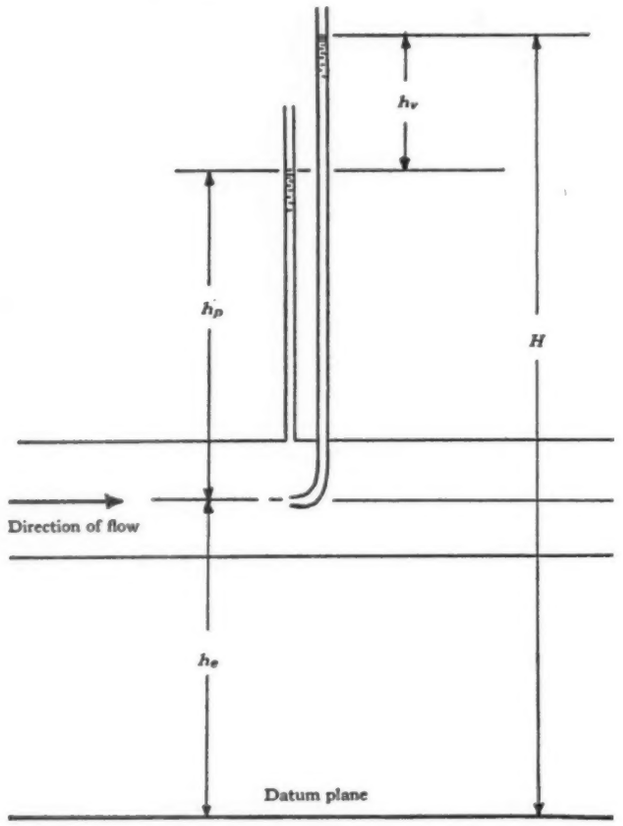


Fig. 40—Total Head

The orifice should be placed in a straight section of horizontal or vertical pipe and should be located as far as possible from bends, fittings, and valves. The diameter of the orifice should not be greater than 75 to 80 per cent of the inside diameter of the pipe. The loss of head in the pipe orifice is quite large and it is less reliable than the Venturi meter.

Water Power

The total available power of flowing water is given by the formula:

$$H.P. = \frac{QwH}{550} = 0.113472\,QH$$

where $H.P.$ = Horse Power.
Q = Discharge in cubic feet per second.
H = Total available head in feet.
w = Weight of one cubic foot of water (at 50° F. = 62.4096 pounds).

The total head may be made up of velocity head, pressure head, and potential head, or head due to actual height above the datum plane. Fig. 40 illustrates the three components of the total head.

The value of the velocity head is given by the expression:

$$h_v = \frac{v^2}{2g}$$

where h_v = Velocity head in feet.
v = Mean velocity in feet per second.
g = Acceleration of gravity = 32.174 feet per second per second.

Table 22
Horsepower for Various Heads of Water

Horse power for 1 cu. ft. of water per second under heads of 1 to 2,000 ft. Based on an efficiency of 80 per cent and weight of water at 50°F. = 62.4096 lb. per cubic foot.

(Horse power per cubic foot of water per second = $\frac{62.4096 \times 0.80 \times H}{550} = 0.0907776\,H$).

Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power	Head in feet (H)	Horse power
1	0.0907776	170	15.4322	420	38.1266	925	83.9693
2	.181555	180	16.3400	430	39.0344	950	86.2387
3	.272333	190	17.2477	440	39.9421	975	88.5082
4	.363110	200	18.1555	450	40.8499	1000	90.7776
5	.453888	210	19.0633	460	41.7577	1050	95.3165
6	.544666	220	19.9711	470	42.6655	1100	99.8554
7	.635443	230	20.8788	480	43.5732	1150	104.394
8	.726221	240	21.7866	490	44.4810	1200	108.933
9	.816998	250	22.6944	500	45.3888	1250	113.472
10	.907776	260	23.6022	525	47.6582	1300	118.011
20	1.81555	270	24.5100	550	49.9277	1350	122.550
30	2.72333	280	25.4177	575	52.1971	1400	127.089
40	3.63110	290	26.3255	600	54.4666	1450	131.628
50	4.53888	300	27.2333	625	56.7360	1500	136.166
60	5.44666	310	28.1411	650	59.0054	1550	140.705
70	6.35443	320	29.0488	675	61.2749	1600	145.244
80	7.26221	330	29.9566	700	63.5443	1650	149.783
90	8.16998	340	30.8644	725	65.8138	1700	154.322
100	9.07776	350	31.7722	750	68.0832	1750	158.861
110	9.98554	360	32.6799	775	70.3526	1800	163.400
120	10.8933	370	33.5877	800	72.6221	1850	167.939
130	11.8011	380	34.4955	825	74.8915	1900	172.477
140	12.7089	390	35.4033	850	77.1610	1950	177.016
150	13.6166	400	36.3110	875	79.4304	2000	181.555
160	14.5244	410	37.2188	900	81.6998	....	.....

Table 25—Pressure Equivalents

Units		Pounds per square inch	Pounds per square foot	Kilograms per square centimeter	Inches of mercury at 32° F.	Feet of water at 39.2° F.	Feet of water at 62° F.	Atmospheres
1 pound per square inch	=	1.	144.	0.0703067	2.0360	2.30671	2.30934	0.068044
1 pound per square foot	=	0.0069444	1.	0.0004882	0.014139	0.016019	0.016037	0.0004725
1 ounce per square inch	=	0.0625	9.	0.0043942	0.12725	0.144169	0.144334	0.0042528
1 kilogram per square centimeter	=	14.2234	2048.17	1.	28.9582	32.8092	32.8467	0.967820
1 kilogram per square meter	=	0.0014223	0.204817	0.0001	0.0028958	0.0032809	0.0032847	9.678×10^{-5}
1 inch of mercury at 32° F.	=	0.49117	70.7285	0.034533	1.	1.13299	1.13428	0.033421
1 inch of water at 39.2° F.	=	0.036127	5.20222	0.0025399	0.073552	0.083333	0.083428	0.0024582
1 inch of water at 62° F.	=	0.036085	5.19628	0.0025370	0.073468	0.083238	0.083333	0.0024554
1 foot of water at 39.2° F.	=	0.43352	62.4266	0.030479	0.88262	1.	1.00114	0.029498
1 foot of water at 62° F.	=	0.43302	62.3554	0.030444	0.88162	0.99886	1.	0.029465
1 atmosphere	=	14.6963	2116.27	1.03325	29.9210	33.9001	33.9388	1.

Table 26—Rate of Flow Equivalents

Units		Cubic feet per second	Cubic feet per minute	U. S. gallons per minute	U. S. gallons per 24 hours	British Imperial gallons per minute	Liters per minute	Acre-feet per hour	Acre-feet per 24 hours
1 cubic foot per second	=	1.	60.	448.831	646 317.	373.729	1698.98	0.082645	1.98347
1 cubic foot per minute	=	0.016667	1.	7.48052	10 771.9	6.22882	28.3163	0.0013774	0.033058
1 U. S. gallon per minute	=	0.0022280	0.13368	1.	1440.	0.83267	3.78533	0.0001841	0.0044192
1 U. S. gallon per 24 hours	=	1.547×10^{-6}	9.283×10^{-5}	0.0006944	1.	0.0005782	0.0026287	1.279×10^{-7}	3.069×10^{-6}
1 British Imperial gallon per minute	=	0.0026757	0.16054	1.20095	1729.37	1.	4.54601	0.0002211	0.0053072
1 liter per minute	=	0.0005886	0.035315	0.26418	380.416	0.21997	1.	4.864×10^{-5}	0.001167
1 acre-foot per hour	=	12.1	726.	5430.86	7 820 434.	4522.13	20 557.6	1.	24.
1 acre-foot per 24 hours	=	0.50417	30.25	226.286	325 851.	188.422	856.567	0.041667	1.

Table 26—Volume and Capacity Equivalents

Units		United States gallons	British Imperial gallons	Liters	Cubic feet	Cubic inches	Acre-feet
1 United States gallon	=	1.	0.832672	3.78533	0.133681	231.	3.069×10^{-6}
1 British Imperial gallon	=	1.20095	1.	4.54601	0.160544	277.420	3.686×10^{-6}
1 liter	=	0.264177	0.219973	1.	0.035315	61.0250	8.107×10^{-7}
1 cubic foot	=	7.48052	6.22882	28.3163	1.	1728.	2.296×10^{-5}
1 cubic inch	=	4.329×10^{-3}	3.605×10^{-3}	0.016387	5.787×10^{-4}	1.	1.329×10^{-8}
1 acre-foot	=	325 851.	271 328.	1 233 456.	43 560.	75 271 680.	1.
1 inch deep on 1 acre	=	27 154.3	22 610.6	102 788.	3 630.	6 272 640.	0.083333
1 inch deep on 1 square mile	=	17 378 743.	14 470 801.	65 784 344.	2 323 200.	4 014 489 600.	53.3333
1 meter deep on 1 hectare	=	2 641 705.	2 199 675.	9 999 734.	353 145.	610 233 780.	8.10708
1 centimeter deep on 1 square meter	=	2.64171	2.19967	9.99973	0.353145	610.234	8.107×10^{-6}
1 pound of water at 39.2° F.	=	0.11983	0.099778	0.45359	0.016019	27.6805	3.677×10^{-7}
1 pound of water at 50° F.	=	0.11986	0.099806	0.45372	0.016023	27.6880	3.678×10^{-7}
1 pound of water at 62° F.	=	0.11997	0.099892	0.45411	0.016037	27.7121	3.682×10^{-7}
1 U. S. gallon per minute for 24 hours	=	1440.	1199.05	5450.88	192.5	332 640.	0.0044192
1 cubic foot per minute for 24 hours	=	10 771.9	8 969.50	40 775.4	1440.	2 488 320.	0.033058

The pressure head is given by the expression:

$$h_p = \frac{P}{w}$$

where h_p = Pressure head in feet.

P = Pressure in pounds per square foot.

The potential head or head due to height above the datum plane is h_e feet.

The total head, H, is therefore:

$$H = h_v + h_p + h_e$$

or

$$H = \frac{v_1}{2g} + \frac{P}{w} + h_e$$

In any stream flowing steadily without friction, the total head, and the total amount of energy per unit of water, is the same at every point in the path of flow. This principle, which is in reality the law of conservation of energy applied to flowing water, is known as Bernoulli's Theorem.

Table 22 gives the horse power for one cubic foot of water per second, under heads of 1 to 2000 feet, based on an efficiency of 80 per cent. The method of using this table is illustrated by the following example:

Determine the horse power which can be developed by a flow of 60 cubic feet per second under a head of 200 feet.

From the table the horse power for a discharge of one cubic foot per second under 200 feet head is found to be 18.1555. The horse power for a discharge of 60 cubic feet per second under 200 feet head is then:

$$60 \times 18.1555 = 1089.33 \text{ horse power.}$$

When the exact head is not given in the table the horse power may be found by multiplying the horse power for one foot head and one cubic foot per second (0.0907776) by the head in feet and then by the discharge in cubic feet per second. For example, the horse power which can be developed by a discharge of 45 cubic feet per second under a head of 105 feet will be:

$$0.0907776 \times 105 \times 45 = 428.92 \text{ horse power.}$$

PRACTICAL HYDRAULICS*

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I. The Sharp Crest Weir

The so called Sharp Crest Weir is a very useful device for the measurement of water flowing in open channels or streams. A knowledge of the few simple rules governing the design and use of weirs will make it possible to measure the flow of water shed streams contributing to reservoirs, to estimate the overflow or leakage of dams and to make other measurements of use to the water works operator.

By a Weir is meant a bulkhead or dam over which the water flows, or more particularly, a notch in the top of such a structure through which the water flows. As shown in the illustration (Fig. 1), it usually consists of a rectangular notch and it is then known as a Rectangular Weir.

The Crest of a weir is the bottom of the notch, the level to which the water must rise before any can flow over. It is the edge or sill over which the water flows. A weir is a Sharp Crest Weir when the bottom edge of the notch, or the crest, is constructed so as to be as sharp as possible, flush with the upstream face of the dam, and with the opening beveled or enlarged on the downstream side so that the stream of water as it passes through the opening will only touch the crest along one sharp edge, as shown in Fig. 2. In the laboratory the crest is kept as sharp as a knife edge. In practice the edge of a metal plate or angle iron, as shown in the illustration, is usually satisfactory unless extreme accuracy is desired. The upstream face of the weir should be vertical, and of course the crest should be exactly horizontal.

The Head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. With any given weir there is a fixed relation between the head and the amount of water being discharged, thus by measuring the head the discharge may be determined from the formula or table which applies to that particular form of weir in use.

The relation between the head and the discharge of a weir is different with different forms of crest and different shapes of notches. Different formulas must be used with such different weirs. The reason for making a weir sharp crested is that by so doing a weir can be built which can be used for the measurement of water without the necessity for making special tests to determine what the formula is. The formula for rectangular sharp crest weirs is known, and it has been found easier to reproduce standard conditions by the use of the sharp crest design than with most other forms. Most weirs built for the measurement of water are therefore constructed as sharp crest weirs.

Weir Formulas

One of the most commonly used formulas for use with rectangular sharp crest weirs is known as the Francis formula, named for its originator, Mr. J. B. Francis, who performed extensive experiments on weirs at Lowell, Mass., in 1851. This formula is as follows:

$$Q = 3.33 \times L \times h \times \sqrt{h}$$

In this formula:—

Q = Discharge of the weir in cubic feet per second.
L = Length of the weir crest in feet.
h = Head on the weir in feet.
$\sqrt{h}$ = The square root of the head in feet. The square root of the head is the number which, multiplied by itself, equals the head.

($h \times \sqrt{h}$ is often expressed as $h^{3/2}$, but it is more readily computed if considered in the form given above.)

Example: A sharp crest rectangular weir is 5.00 feet long and has a head of 0.42 feet (5 inches) on it.

(The square root of 0.42 is 0.65, because $0.65 \times 0.65 = 0.42$.)

$Q = 3.33 \times 5.00 \times 0.42 \times 0.65 = 4.55$ cu. ft. per second.

The Francis formula given above is most accurate for heads between about 0.30 feet and 2.00 feet. A small error in determining the head makes such a large error in the discharge at very low heads, that for most practical purposes this formula is sufficiently accurate at all heads up to about 2.00 feet, and it is fairly accurate for higher heads also. The great advantage of the Francis formula is the fact that it is much simpler to compute than most of the others. The principal other formulas are known as the Bazin formula, the Fteley and Stearns formula and the Rehbock formula. A complete treatise may be referred to for the details of these other formulas.

For convenience the results of the computations from a weir formula may be arranged in a table, as shown in Table I. The discharge read from the table may be multiplied by the length (in feet) of any sharp crest weir to obtain the discharge.

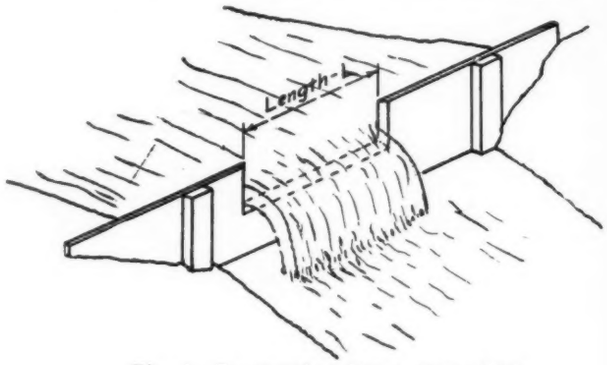

Fig. 1—Rectangular Sharp Crest Weir

TABLE I—DISCHARGE OF A SHARP CREST WEIR PER FOOT OF LENGTH BY THE FRANCIS FORMULA

Head Expressed in Feet	Head Expressed in Inches	Discharge per Foot of Length of Weir Expressed in Cubic Feet per Second	Discharge per Foot of Length of Weir Expressed in Gallons per Minute
.01	1/8	.0033	1.5
.02	1/4	.0094	4.2
.03	3/8	.0173	7.8
.04	1/2	.0266	11.9
.05	5/8	.0372	16.7
.06	3/4	.049	22.0
.07	7/8	.062	27.7
.08	1	.075	33.8
.09	1 1/8	.090	40.4
.10	1 1/4	.105	47.2
.12	1 1/2	.138	62.
.14	1 5/8	.175	78.
.16	1 7/8	.213	96.
.18	2 1/8	.254	114.
.20	2 3/8	.298	134.
.22	2 5/8	.344	155.
.24	2 7/8	.392	176.
.26	3 1/8	.441	198.
.28	3 3/8	.49	222.
.30	3 5/8	.55	246.
.32	3 7/8	.60	271.
.34	4 1/8	.66	296.
.36	4 3/8	.72	323.
.38	4 1/2	.78	350.
.40	4 3/4	.84	378.
.42	5	.91	407.
.44	5 1/4	.97	436.
.46	5 1/2	1.04	467.
.48	5 3/4	1.11	497.
.50	6	1.18	530.
.55	6 5/8	1.36	610.
.60	7 1/4	1.55	690.
.65	7 3/4	1.75	780.
.70	8 3/8	1.95	870.
.75	9	2.16	970.
.80	9 5/8	2.38	1070.
.85	10 1/4	2.61	1170.
.90	10 3/4	2.84	1270.
.95	11 3/8	3.08	1380.
1.00	12	3.33	1500.

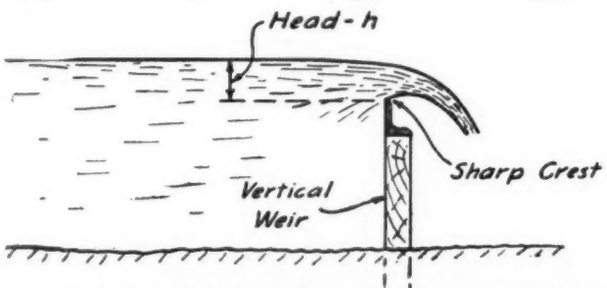

Fig. 2—Cross Section Rectangular Sharp Crest Weir

(*Continued on page 364*)

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II. The End Contractions of a Weir

There are two methods of constructing the ends of the weir. The first of these is shown in Fig. 3 and results in what is known as a weir *with end contractions.* In this design the sharp crest of the weir as formed by the bottom of the notch is continued up the ends of the notch, thus forming sharp edged ends for the weir. The water in flowing around these sharp corners then follows a course very similar to that taken in flowing over the edge of a sharp crest. In flowing around the edge from behind the weir it cannot change direction sharply and it curves inward toward the center of the weir contracting the stream as shown in the illustration.

The other method of designing the ends of the notch is to build it so that it extends the full width of the stream at that point, allowing the sides of the channel to form the ends of the notch and continue upstream at that width for a short distance, at least. An example of this method of construction is shown in Fig. 4. When so built it is known as a weir *without end contractions* because the water in this case flows straight over the crest, the stream continuing full width all the way. The weir thus consists of a simple dam or bulkhead across the channel.

It may readily be seen that if two rectangular sharp crest weirs have the same length and are flowing under the same head, the one that has end contractions (Fig. 3) is not discharging as much water as the weir without end contractions (Fig. 4). It has been found by experimentation that with sharp edged ends and a wide channel above the weir, so that the over-falling stream is fully contracted, the effect on the discharge of the weir is the same as if the length of the weir were reduced by a distance equal to one-tenth (0.1) of the head at each end of the weir.

For example: A sharp crested, rectangular, vertical weir is three feet long and the ends are so constructed that the flow will be fully contracted. If the head is one foot, then the effective length of the weir is reduced by one-tenth of a foot at each end making its effective length (3.0 — O.z) = 2.8 feet—a reduction in capacity of about 7 per cent from the capacity it would have had without end contractions. Failure to make this correction might constitute a rather serious error.

If the head on the same 3 foot weir were only 0.1 foot instead of 1.0 foot (or if the length of the weir were increased to 30 feet with a head of 1.0 feet) then in either case the reduction in effective length would be only about 0.7 per cent which

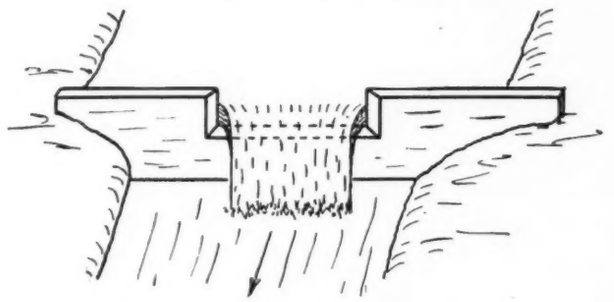

Fig. 3—Weir with End Contractions

would be a negligible error except in the most precise measurements.

It is thus seen that the importance of making the correction for end contractions depends upon the relative head and the length of the weir. If the head is more than one twentieth (5 per cent) of the length then end contractions will require a correction of more than 1 per cent and should certainly be accounted for.

Weirs are seldom operated in practice under a head sufficiently great in proportion to the length that the correction for end contractions is of importance. In such cases it is evident that it does not matter how the ends of the weir are built. Many weirs under practical conditions are built so that they do not have theoretically sharp edged ends and yet neither are they ended against the sides of the stream channel. The ends may merely be formed by the wood or masonry of which the dam bulkhead is built. In such cases we know that there is some end contraction but we do not know how much. Such a weir should be checked up to determine whether the end contraction correction would be of importance if it were complete. If it is found that the relation between the maximum head and the length of the weir is such that the correction would not be

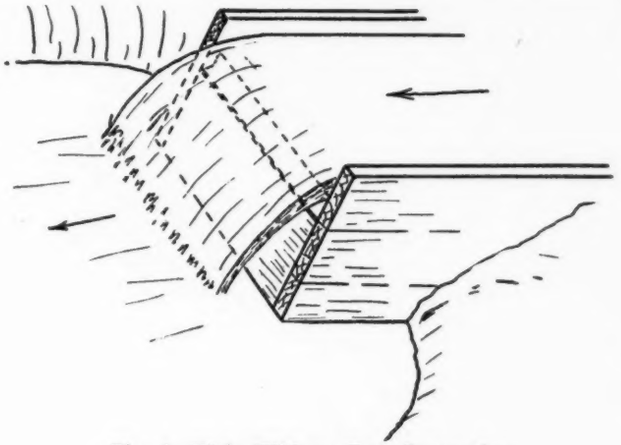

Fig. 4—Weir Without End Contractions

of importance (less than 1 per cent), then we know that it does not matter what it actually is and it can be neglected. It is found that the end contraction correction is of importance then either it must be estimated or else actual measurements of the flow must be made to determine what the correction actually should be. Usually it can be estimated. It is a help in estimating to actually observe the form of the stream during discharge of the weir.

If the relation between the length of the weir and the head is to be such that the end contraction correction will be of importance then the weir should, if possible, be built either with full contractions or with none at all so that the correction will be definitely known.

A weir may be built with a sharp edge on one end only so that the end has a full contraction and so that the other end has no contraction. The correction in such a case is, of course, only one-tenth of the head to be subtracted from the weir length.

III. Measurement of Head on Weirs

The measurement of flowing water by means of a weir depends in turn upon the measurement of the *head* of water on the weir. Having determined the weir formula to be used, depending upon the design of the weir crest, the presence or absence of end contractions and any other fixed condition, the recorded flow then depends upon the head. The head is the single remaining variable quantity. It is the quantity which is actually observed and measured in the field, the desired knowledge as to the amount of water flowing being then computed by the use of the formula, table or diagram. It is assumed in this discussion that the flow over the weir is not affected by backwater from below.

The head on a weir is the difference in elevation between the crest of the weir and the surface of the water in the pool upstream from the weir. Figure 1 is a vertical cross section through a sharp crest weir with water flowing over it under a head indicated by (h). The shape of the upper and lower water surfaces shown in this figure have been determined by measurement and have been found to have forms similar to these, regardless of what the head is, so long as the weir has a sharp crest and a vertical upstream face. Under special conditions at low heads the water may, however, cling to the downstream face of the weir.

Figure 1 shows clearly the fact that in this general case the

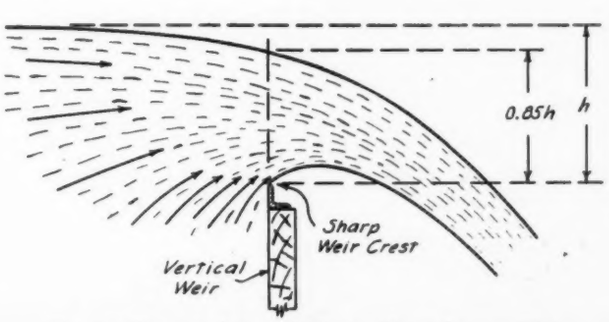

Fig. 1—Characteristics of Water Flow Over a Weir

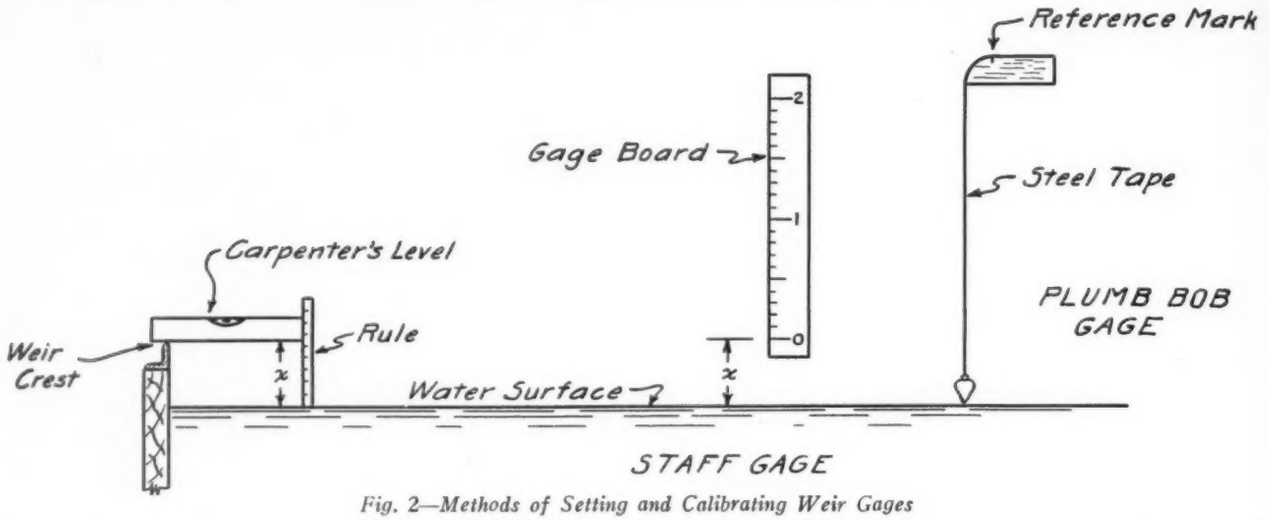

Fig. 2—Methods of Setting and Calibrating Weir Gages

water only touches the crest along the one sharp edge and then leaps free. The arrows showing the converging stream indicate the reason for the shape which the lower surface of the water is found to take. There is one very important fact to be noted from Figure 1—namely, the upper surface of the water starts to curve downward before it reaches the weir. This results in the depth of water at the weir crest actually being only about 85/100ths of "h" (expressed as 0.85h)—the condition which makes it necessary to measure the height of the water surface at some distance upstream from the weir when determining the head. The height of the water surface should be measured at a point located upstream from the weir *a distance at least equal to three times the maximum head* to be encountered.

Measuring Gages

The type and design of gage to be used to determine the water level depends upon the accuracy desired and the conditions under which it will operate.

The Staff-Gage

The simplest and most commonly used type of gage consists merely of a strip of wood or metal with the necessary graduations marked upon it. A section of a carpenter's rule or a surveyor's rod may be used if adequately waterproofed by varnishing. One of the best forms of gage board consists of a vitreous enameled ware metal plate mounted on a wood plank. The graduations and figures are baked into the enamel. Gages such as these, often called staff-gages, if well graduated and carefully read will enable the water level to be determined to within about 0.01 feet, equivalent to about ⅛ inch. This is sufficiently accurate for most purposes other than studies requiring laboratory refinements. One of the greatest disadvantages of this type of gage, however, is the necessity for locating the observer's eye near the water level when taking a reading. This is not always convenient. Care must be taken to read at the true water surface and not the height to which the water surface curves upwards where it wets the gage.

When mounting a staff-gage great care is needed to insure that the zero of the gage is exactly level with the crest of the weir and that it remains so. A small error in this respect will cause a large error in the results, particularly at low heads. Moreover, this error will always be in the same direction and will not tend to correct itself or be compensated for by other errors.

By the careful use of a surveyor's level a gage may be set with sufficient accuracy. If a surveyor's level is not available then the water surface itself may be used in the manner indicated in Figure 2. Choose a time when the water surface is not rising or falling too rapidly and preferably when it is lower than the weir crest. By means of a carpenter's hand level and rule measure the distance (x) down to the water surface from the weir crest. Then measure up from the water surface at the gage location and set the gage zero the same distance (x) above the water level as the weir crest was found to be. Then, afterward, such gages should be regularly checked to be certain that they have not been moved, and that the zero point is correct.

Plumb-Bob Gage

Another form of gage is known as a plumb-bob gage. It consists of a graduated steel tape with a heavy plumb bob on its end. It is used to measure from a fixed reference mark, above water level, down to the water surface. By allowing it to swing slightly the contact of the plumb bob with the water surface may be very accurately noted. This naturally assumes the water surface to be smooth. The plumb-bob gage may be most accurately read if the tape is run over a curved block of wood, mounted permanently above the water, which has the reference mark fixed on its upper surface, as indicated in Figure 2. The zero reading on this type of gage may be determined by measuring down to the water surface from the weir crest as shown in Figure 2 and applying the correction factor determined by a simultaneous reading of the tape.

Chain Gage

A similar type of gage known as a chain gage is often used. For the tape a chain running over a wheel is substituted. With this arrangement the position of a marker attached to the chain above the wheel is read along a horizontal scale. This type of gage is not so accurate as the former and it is not advised for weir readings except in the case of rough work or high heads. It is often used for river heights where accuracy within about 0.05 feet is generally satisfactory.

With all types of gages difficulty is introduced if the water level is disturbed by waves or surges. In the case of the gages above described this can only be overcome by the skill and patience of the operator in mentally averaging the indications while observing them over a short period. Practice can develop considerable skill in doing this.

IV. The Float Gage

Probably the most accurate type of gage, if well designed and constructed, is a float gage. Besides its accuracy it also has other advantages. Difficulty in reading due to waves and surges may be most readily overcome with the float type gage which is readily adapted to the use of an automatic recording mechanism. They may be classified into two types. The simplest type consists of the float with a rigid vertical stem attached to and supported by the float, with an index or pointer at its upper end. The gage reading is obtained from the position of this pointer along a fixed vertical scale. In the other type of float gage the motion of the float is transmitted to some form of indicating or recording mechanism by means of a flexible wire or tape.

The Float

A suitable float is the first essential. It must not become water logged, but must retain its buoyancy. To meet this condition a hollow sheet metal float is generally used, and copper is the preferred material because of its resistance to corrosion. The seams must be well locked and thoroughly soldered. Earthenware floats have been used in sewage or other corrosive liquids. Floats are most often made cylindrical with the axis vertical, in order to fit in a float pipe and, for ease of construction. It is important to have the top and bottom dished outward so that the float cannot be weighted with water on top or lifted by air trapped beneath. The float should have at least three vertical fins projecting a half inch or more from its sides in order to prevent it from clinging to the wall of the float pipe or well. Sometimes a spherical float is used, but in that case its weight, or its counterweight, should be adjusted so that it will float near its middle, in order to gain the maximum sensitivity.

Float Pipe

Floats are usually provided with some form of float pipe or stilling well. This serves two principal purposes—it serves as a guide for the float, and by adjusting the size of the communicating opening into the float pipe the effect of waves or surges upon the gage readings may be reduced. The use of a float pipe also makes it possible to locate the gage a short distance away from the body of water being observed, the level in the float pipe being maintained by a small size connecting pipe. With such an arrangement care must be exercised to avoid air traps in the connecting pipe. The connecting pipe should be made of non-corrosive material and should be provided with convenient means for flushing it out. A float pipe should be provided with a cover, having only a small opening for the wire or tape, in order to prevent objects from falling in and lodging on the float.

If the gage mechanism is light and easily operated, a 5-in. diameter float in a 6-in. float pipe makes a good combination. If a high degree of sensitivity is desired, or if a recorder requiring some power to operate it is used, then a larger float is desirable, a 10-in. float in a 12-in. pipe, or even larger, being often used.

Gage With Rigid Stem

The type of float gage having a rigid stem is the simplest and is also probably capable of the closest reading with accuracy, since the only friction involved in its motion is due to whatever guides may be needed to keep the stem upright and in the correct position with relation to the scale. The effect of this friction in preventing accurate response of the gage to changes in the water level may be largely if not entirely avoided by gently tapping the stem while reading the gage. Gages of this type, if properly designed and constructed, may be read directly to the nearest one thousandth of a foot (0.001 ft.), which is about the best in true accuracy that can be expected from single readings of any type of gage.

An arrangement of this type of gage, which has been used extensively and which is highly suitable for accurate weir head readings, is shown in Fig. 1. In this design a 7-in. float may be used in an 8-in. float pipe. The float stem is a brass rod of about 3/16 in. or ¼ in. diameter, depending on the height. The best scale is made from a graduated brass strip about ⅛ in. thick. It is provided with a continuous projection along its back edge which serves to guide the index or pointer in the correct position for easy reading, and to hold the stem vertically above the float.

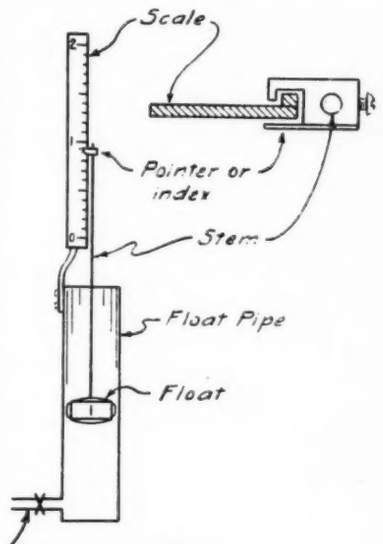

Fig. 1—Float Gage with Stem

Gage With Flexible Wire

The second type of float gage, using a flexible wire or tape, is more adaptable to different arrangements, since the motion is usually converted into a rotary motion by the wheel or drum on which the wire is wound, and thus the readings may be shown on a circular dial, or a recording mechanism may be operated. It is not always so simple to overcome the friction of motion in this type of gage, and for that reason it may not be read quite so accurately unless the float is larger than with the rigid stem type.

A metal wire or tape is necessary for accurate readings in order to avoid changes in length due to stretching or moisture. The wire should be stranded, made from a large number of very small wires braided together, in order to be flexible and withstand frequent bending. Either wire or tape must be of bronze or other non-rusting metal.

The simplest arrangement of this type of gage consists merely of passing the wire over a wheel or pulley and having a counterweight on the end. Reading may then be taken from the motion of a pointer attached to the wire along a fixed vertical scale beside it. A very crude form of such a gage has often been seen on railroad water tanks.

A more usual arrangement in water works practice is to attach the end of the float wire to a drum, around which it is then wound a number of turns. The counterweight is then hung from another wire similarly attached to the drum. By such design slipping of the wire is avoided and the revolution of the drum is a true measure of the change in water level. The drum is then connected to a rotating pointer on a dial or to a recording device. By introducing suitable gearing a wide range of float motion may be shown as only a part of a revolution of the pointer on the dial, or other variations may be introduced changing the scale of readings to suit the conditions and the requirements.

The drum upon which the wire is wound should be provided with spiral grooves to receive the wire so that it will be guided in a single layer and will not wind upon itself, thereby changing the effective diameter of the drum and affecting the accuracy of the gage. If desired, the drum receiving the counterweight wire may be smaller than the drum for the float wire, thereby resulting in a shorter travel for the counterweight where this is of any advantage. The counterweight should not become submerged, since its effective weight would thereby be altered and the submersion of the float changed.

Gage With Tape

If a tape is used it is customary to provide it with uniformly spaced perforations which fall over similarly spaced projecting pins on the drum, thereby preventing slipping. A tape is, of course, not wound around the drum, but merely passes over it once, with the counterweight on the end. The counterweight must then travel through the same range of motion that the float does.

Indicators and Recorders

Many good designs of indicating and recording instruments are commercialy available for use with floats and which are adaptable to different conditions and requirements. Floats may also be utilized similarly to operate transmitters for long distance electrical transmission of gage readings, known as telemeters.

CENTRIFUGAL PUMPS*

Some Notes on Selection of the Proper Pump and A Simple Method of Checking Pump Efficiencies

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SOME twenty years ago when I first entered the water works field steam driven displacement type pumps were in general use. But, today we find the great majority of pumping stations equipped with electrically driven centrifugal pumps, with an occasional Diesel driven or turbine driven centrifugal installation. The old slow moving reciprocating pump of yesterday could always be depended upon to take care of changing pumping loads and varying heads without any great loss in efficiency. But, this is decidedly not so with the modern centrifugal pump, designed to work under rather fixed conditions. Any appreciable variation from these conditions is accompanied by a falling off in efficiency, which may be rather marked.

Unfortunately, the non-technical water works operator who got his early practical experience with the old displacement type of pump has not always become sufficiently acquainted with the characteristics of the centrifugal pump. Only too often the only demand made on a centrifugal pump is that it pump water, and little or no attention is paid to the efficiency with which it does its work. In fact the average water works man is usually not acquainted with any simple method of determining this efficiency.

It is, therefore, the purpose of this article to point out the conditions which may be expected to cause low operating efficiency, and to outline a simple method for testing the wire-to-water efficiency which gives results as close as is necessary in practical water works operation.

Basic Principles of the Centrifugal

As a youngster I used to tie a chestnut on the end of a string and whirl it around my head until I had imparted to it the force necessary to take it flying through the air at high speed. You did it, too. The principle of building up velocity of that chestnut by whirling it about the head is the same principle which is used in the design of a centrifugal pump. The water which enters the pump through the suction inlet is seized by the rotating vanes of the impeller and spun until it is rotating at terrific velocity. Since pressure and not velocity is desired, the pump is so designed that by gradually slowing down this velocity in the casing of the pump, the energy stored up in this rapidly moving water is almost entirely changed to pressure. The speed of the chestnut rests upon two factors—the length of the string and the number of revolutions made within a specified period of time. The speed, and hence the resulting pressure, imparted to water by a centrifugal pump also rests upon the same two factors—the diameter of the impeller and the number of revolutions per minute which the impeller makes.

There are, of course, practical limits to both the speed and the diameter so that it is not always possible to secure the full desired pressure with one pump. If not, the water is passed through two or more pumps in series, and each pump raises the pressure part of the total desired amount. Sometimes these two or more pumps are built in one pump case, in which instance each pump is called a "stage" Since electrically driven centrifugal pumps operate at fixed speeds, there is always one head under which a pump will operate most efficiently. Right here it will not hurt to repeat that any material deviation from this condition will result in decreased efficiency.

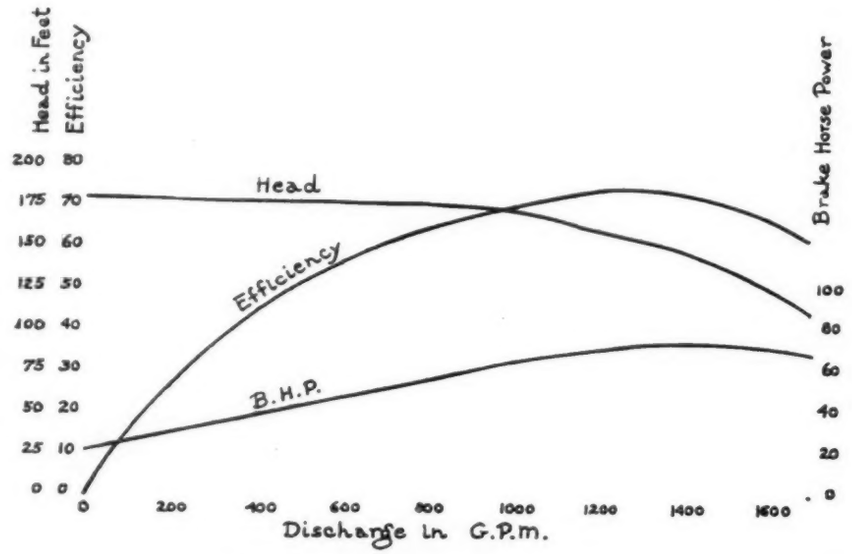
Pump Performance Curves

At this point I want to introduce a typical centrifugal pump curve which we will use for illustration during this discussion. Similar curves are available from the manufacturer for all medium sized and large pumps. On small pumps it is not customary to furnish such performance curves.

It will be noted from an inspection of the specimen curve that the greatest efficiency for this particular pump (about 75%) is secured when the head is about 155 ft. and the discharge rate is about 1,300 G.P.M. You will also note that as the head is materially increased or decreased from the optimum head there is a large change in the pumping rate and a considerable drop in efficiency. A great deal has been done in design effort to widen out the "peak" of the efficiency curve into a "plateau" so as to give high efficiencies for centrifugal pumps under a wider range of operating conditions. Considerable progress has been made in this direction.

Friction Head—Its Importance

Let us see what happens when we forget to include pipe friction loss when figuring the total head against which the pump must operate. If we have figured on the pump whose curve we have, and if we are pumping through two miles of 16" main, the friction loss will add about 18 ft. to the pumping head—making it 173 ft. At this head (see curves) the pumping rate will drop to 1,000 G.P.M. and the efficiency to 70%. Furthermore, the pump is operating on a very critical part of the curve where a slight increase in pumping head—caused by tuberculation in the main or by any other reason—would incur a precipitate drop in both the efficiency and the pumping rate. It also illustrates what can happen to a pump, after installation, when the pumping head has been increased above the head for which it was designed. As



An Example of Typical Performance Curves for Centrifugal Pumps. Various designs show individual characteristics in respect to the curves produced.

* Excerpts from a paper presented before the Penna. Water Operators Association and an earlier article by Mr. Beckwith in previous Reference & Data Issues of this magazine.

it is the nature of unlined iron and steel mains to tuberculate, resulting in a constantly rising friction loss, this is an important consideration.

Let us illustrate this in another way.

Selecting the Right Pump

Suppose that we are in the market for a 1,000 G.P.M. pump operating against a total head of 173 ft., and a pump whose curve we have been using has been submitted for consideration. I would not consider this pump a good "buy" to operate under these conditions. In the first place it will be noted that the efficiency of 70% is much below the maximum efficiency of 75%. But even more important, perhaps, is the fact that the pump at 173 ft. head is operating under "critical head" conditions. An increase of only about 8 ft. (less than 5%) in the pumping head would bring the head to the maximum which the pump can create—in other words to the "cut off" point. This means that an increase in the head of only 8 ft. (about 3½ pounds) would decrease the pumping rate from 1,000 G.P.M. to zero G.P.M. Moreover an increase of only 3 ft. in head would cause a drop of 200 G.P.M. in the pumping rate. On the other hand, when we are working in the most efficient range of the pump a change of 3 ft. in the head would only cause a variation of 30 to 40 G.P.M. in the pumping rate; and, the efficiency is practically unaffected.

It follows, therefore, that one should buy a pump within the range where the efficiency curve is as *flat* as possible and the head curve is as *steep* as possible. In this connection a word of warning may not be amiss. By making the vertical scale of the curve less than is customary a much flatter *appearing* efficiency curve can be secured. So in comparing the performance curves of pumps be sure that they are plotted on comparable scales. I have known curves with reduced vertical scales to be submitted where I felt sure that the scale was deliberately reduced for the purpose of deception.

Mistaken Economy

Only too often in the revamping of a plant, efforts are made to re-use as much of the old equipment as possible. It may be assumed that if the old pump will handle 1,300 G.P.M. against 155 ft. of head it should have less trouble pumping the same amount from the river to the settling basin against a head of only forty or fifty feet. This is so. In fact, if we will look at the curve we will find it will pump much more than 1,300 G.P.M. at the lower head. The curve does not go out that far, but it goes far enough to show what would happen—not only to the pumping rate but to the efficiency as well. The pumping *rate goes up* but the *efficiency goes down*—yes, way down. Reducing the head has a tendency to cause a pump to run away much as an automobile would run away down hill when the going becomes easier if the throttle were not closed to compensate for the decreased demand for power. This running away of the pump sometimes overloads the motor so that it runs hot. To prevent this, operators raise the head artificially by partly closing a valve on the outlet side of the pump. This decreases the load on the motor and brings the pumping rate back to normal. But it burns up a great deal of power needlessly as the closed valve destroys part of the head generated by the pump and only part of the work actually performed is effective. I have known of installations, such as this, where the installation of a new pump saved more than enough power in one year to pay the entire cost of the new pump and motor and also completely depreciate the old unit replaced.

But it is not always necessary to buy a new pump just because the head has been reduced. If we will get back to that chestnut on the string we will find that we can reduce the speed of the chestnut by reducing the length of the string, at the same time keeping the number of revolutions constant. In the same manner, we can cut down the pressure generated by a constant speed centrifugal pump by reducing the diameter of the runner. If the reduction in head is moderate, the manufacturer can advise you how much will have to be machined off the outside of the present impeller so that it will pump efficiently, or at a slight expense he will furnish a new impeller for the changed conditions. Or he may cut down your old impeller.

It is sometimes possible to secure a larger impeller to efficiently handle increased heads, but in this case the motor is likely to be overloaded unless the original specification anticipated such change as loads increased.

Another way to increase the speed of that chestnut would be to keep the length of the string constant and to increase the number of revolutions. It follows that if we increase the revolutions of any centrifugal pump we will increase the head which that pump will generate. This explains why a certain pump tested last fall gave a wire to water efficiency of only 40%. This pump was designed for use with a gasoline motor and to operate under the then existing head conditions at a speed of 1400 R.P.M. Eventually electric power became available and the pump was connected to an electric motor and the speed increased to 1,800 R.P.M. This, of course, increased the head generated by the pump itself, and the efficiency was consequently very low.

A somewhat similar condition was found several years ago when a 5 M.G.D. installation designed to work against a head of 100 pounds was found to have been connected in series to a 5 M.G.D. pump designed to pump against 50 pounds pressure. This gave an installation with a design head of 150 pounds, but the actual head was still only about 100 pounds. The *output* was thereby *increased* to approximately 6 M.G.D. but the *efficiency decreased* to the point where it was only slightly above 40%. New and properly designed equipment brought the wire-to-water efficiency up to about 75%.

It can be readily seen from the above considerations that the chances of buying a suitable pump from the "junk man" are just about nil. It might be "as good as new" for the conditions for which it was designed and yet be absolutely worthless under any other conditions. In fact, it would probably be a most expensive liability. Yet pumps have been bought from the equivalent of "junk men", but most frequently have been "salvaged" by the original purchaser for other duty than originally purchased for.

So far, we have been discussing equipment which has been working under conditions which made it impossible to give a creditable showing. A mere inspection of the conditions and a knowledge of the design limitations would make it evident that satisfactory performance under these conditions could not be secured. However, there are occasions where, after installation, things happen to properly selected pumps which will cut the efficiency of the equipment. There was, for instance, the time

Table I—Gallons of Water Delivered per Kilowatt Hour Against Various Heads on Theoretical Assumption That Pump and Motor Are 100 Per Cent Efficient

H = head in feet. G = gallons per kilowatt hour

H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G	H	G
1	318,200	51	6,240	101	3,151	151	2,108	201	1,583	251	1,268	301	1,058	351	907	401	794	451	706
2	159,100	52	6,120	102	3,120	152	2,094	202	1,575	252	1,263	302	1,054	352	904	402	792	452	704
3	106,100	53	6,005	103	3,090	153	2,080	203	1,567	253	1,258	303	1,051	353	902	403	790	453	703
4	79,560	54	5,894	104	3,060	154	2,067	204	1,560	254	1,253	304	1,047	354	899	404	788	454	701
5	63,650	55	5,786	105	3,031	155	2,053	205	1,552	255	1,248	305	1,044	355	897	405	786	455	700
6	53,040	56	5,683	106	3,002	156	2,040	206	1,545	256	1,243	306	1,040	356	894	406	784	456	698
7	45,460	57	5,583	107	2,974	157	2,027	207	1,537	257	1,239	307	1,037	357	892	407	782	457	697
8	39,780	58	5,487	108	2,947	158	2,014	208	1,530	258	1,234	308	1,033	358	889	408	780	458	695
9	35,360	59	5,394	109	2,920	159	2,002	209	1,523	259	1,229	309	1,030	359	887	409	778	459	694
10	31,830	60	5,304	110	2,893	160	1,989	210	1,516	260	1,224	310	1,027	360	884	410	776	460	692
11	28,930	61	5,217	111	2,867	161	1,977	211	1,508	261	1,220	311	1,024	361	882	411	775	461	691
12	26,520	62	5,133	112	2,842	162	1,965	212	1,501	262	1,215	312	1,020	362	879	412	773	462	689
13	24,480	63	5,051	113	2,816	163	1,952	213	1,494	263	1,211	313	1,017	363	877	413	771	463	687
14	22,730	64	4,972	114	2,794	164	1,940	214	1,487	264	1,206	314	1,014	364	875	414	769	464	686
15	21,220	65	4,896	115	2,766	165	1,929	215	1,480	265	1,202	315	1,011	365	873	415	767	465	684
16	19,890	66	4,822	116	2,744	166	1,917	216	1,474	266	1,197	316	1,007	366	870	416	765	466	683
17	18,720	67	4,750	117	2,720	167	1,906	217	1,467	267	1,193	317	1,004	367	868	417	763	467	682
18	17,680	68	4,680	118	2,697	168	1,894	218	1,460	268	1,188	318	1,001	368	865	418	761	468	680
19	16,750	69	4,611	119	2,674	169	1,883	219	1,453	269	1,184	319	998	369	863	419	760	469	679
20	15,910	70	4,547	120	2,652	170	1,872	220	1,447	270	1,179	320	995	370	860	420	758	470	677
21	15,150	71	4,482	121	2,630	171	1,861	221	1,440	271	1,175	321	992	371	858	421	756	471	676
22	14,470	72	4,420	122	2,609	172	1,851	222	1,434	272	1,170	322	989	372	856	422	754	472	675
23	13,830	73	4,360	123	2,588	173	1,840	223	1,427	273	1,168	323	986	373	854	423	753	473	674
24	13,260	74	4,301	124	2,567	174	1,829	224	1,421	274	1,162	324	982	374	851	424	751	474	672
25	12,730	75	4,243	125	2,546	175	1,819	225	1,414	275	1,158	325	979	375	849	425	749	475	671
26	12,240	76	4,188	126	2,526	176	1,809	226	1,408	276	1,154	326	976	376	847	426	747	476	669
27	11,790	77	4,133	127	2,506	177	1,798	227	1,402	277	1,150	327	973	377	845	427	746	477	668
28	11,370	78	4,080	128	2,486	178	1,788	228	1,396	278	1,146	328	970	378	842	428	744	478	666
29	10,970	79	4,028	129	2,467	179	1,778	229	1,390	279	1,142	329	968	379	840	429	742	479	665
30	10,610	80	3,978	130	2,448	180	1,768	230	1,384	280	1,137	330	965	380	838	430	740	480	663
31	10,270	81	3,929	131	2,429	181	1,758	231	1,378	281	1,133	331	962	381	836	431	739	481	662
32	9,945	82	3,882	132	2,411	182	1,749	232	1,372	282	1,129	332	959	382	833	432	737	482	660
33	9,644	83	3,834	133	2,393	183	1,739	233	1,366	283	1,125	333	956	383	831	433	736	483	659
34	9,360	84	3,789	134	2,375	184	1,729	234	1,360	284	1,121	334	953	384	829	434	734	484	658
35	9,093	85	3,744	135	2,358	185	1,720	235	1,354	285	1,117	335	950	385	827	435	732	485	657
36	8,840	86	3,701	136	2,340	186	1,711	236	1,349	286	1,113	336	947	386	825	436	730	486	655
37	8,601	87	3,658	137	2,323	187	1,702	237	1,343	287	1,109	337	945	387	823	437	729	487	654
38	8,375	88	3,617	138	2,306	188	1,693	238	1,337	288	1,105	338	942	388	820	438	727	488	652
39	8,160	89	3,576	139	2,292	189	1,684	239	1,332	289	1,102	339	939	389	818	439	725	489	651
40	7,956	90	3,536	140	2,274	190	1,675	240	1,326	290	1,098	340	936	390	816	440	723	490	650
41	7,762	91	3,497	141	2,257	191	1,666	241	1,320	291	1,094	341	934	391	814	441	722	491	649
42	7,577	92	3,458	142	2,241	192	1,658	242	1,315	292	1,090	342	931	392	812	442	720	492	647
43	7,401	93	3,422	143	2,225	193	1,649	243	1,310	293	1,087	343	929	393	810	443	719	493	646
44	7,233	94	3,386	144	2,210	194	1,640	244	1,304	294	1,083	344	926	394	807	444	717	494	644
45	7,072	95	3,350	145	2,195	195	1,632	245	1,299	295	1,079	345	923	395	805	445	716	495	643
46	6,916	96	3,315	146	2,180	196	1,624	246	1,294	296	1,075	346	920	396	804	446	714	496	642
47	6,771	97	3,281	147	2,165	197	1,615	247	1,288	297	1,072	347	918	397	802	447	712	497	641
48	6,630	98	3,248	148	2,150	198	1,608	248	1,284	298	1,068	348	915	398	800	448	710	498	639
49	6,495	99	3,215	149	2,136	199	1,600	249	1,278	299	1,065	349	913	399	798	449	709	499	638
50	6,365	100	3,183	150	2,122	200	1,592	250	1,273	300	1,061	350	910	400	796	450	707	500	636

when we found a water snake wrapped around the shaft with the result that the inlet ports were partially cut off and the suction lift increased way beyond the 15 feet maximum for best performance. In another and similar situation blocks of wood were found jammed in the ports. Then there was the time that low efficiency was caused by the blowing of the gasket of a multiple stage pump and the water was short circuiting back from a higher stage to a lower stage. One of our engineers once reported that an efficiency of 20% was caused by the impeller slipping on the shaft.

Two interesting conditions have been found by the author which have no reference to the actual efficiency of the pumps but which were determined as th result of making efficiency tests. In one instance, where the meter through which power was purchased was used to measure the power input, it was found that an apparent low efficiency was caused by this meter being set 20% high. In another instance, a pump was discharging into a closed distribution system. On the basis of the water *actually discharged* into the system (24-hour period) the pump had an efficiency of only 8%. Had a standpipe or reservoir been floating on this system, the same amount of water could have been pumped with about one-eighth the amount of power which was actually used.

So much for the reasons why efficiency tests should be made at intervals.

A Simple Efficiency Test

The writer has worked out a simple method for making efficiency tests which he has been using with satisfactory results for some years.

At one foot of head and 100% efficiency of *both pump and motor* it is theoretically possible to raise 318,200 gallons of water one foot with one KW.H. To determine this theoretical value for any other head, simply divide 318,200 by the head involved. For instance, the value at 150 ft. would be $\frac{318{,}200}{159} = 2{,}002$ gallons per KW.H. In this connection the accompanying "Table of Theoretical Values for Various Heads" may prove helpful in reducing calculations in pump testing. It was prepared by the writer and has appeared in earlier Reference and Data Numbers of WATER WORKS AND SEWERAGE.

To determine the *wire-to-water efficiency* of an installation it is only necessary to divide the actual pumpage per KWH by the theoretical value for the pumping head, as determined from the table. A rough check can be made by dividing the month's pumpage in gallons by the KWH consumed. This gives the gallons actually pumped per KWH.

Test Procedure

With the pump running, determine the total head in feet (including suction) against which the pump works. Divide 318,200 gallons by this total head (as above) to determine the theoretical 100% pumpage per KWH. (Or take the figure from Table 1.) Next divide the actual gallons per KWH by the theoretical gallons per KWH to secure the wire to water efficiency.

To illustrate:

Assume a monthly pumpage of 32,640,000 gallons and a monthly power consumption of 30,200 KWH. Say the total head noted was 220 ft. Dividing 32,640,000 by 30,200 gives an actual pumpage of 1,081 gallons per KWH. Dividing 318,200 by 220 ft. gives a theoretical value of a possible 1,447 gallons per KWH at 100% efficiency (see table). Then;

$$\frac{1{,}081 \text{ (observed)}}{1{,}477 \text{ (theoretical)}} = 74.7\% \text{ overall}$$

wire to water efficiency.

A more accurate method of making the tests is to measure the power input for an hour, or some other convenient period of time. During this period carefully check the output of the pump with any suitable main line meter. Keep a close record also of the discharge pressure and of the suction. The integrations on most electric meters in pumping stations cannot be read closely enough for short tests. However, the power company will furnish the number of watts consumed for each revolution of the disk, and by counting its revolutions for ten or twenty minutes the rate of power input can be closely ascertained. Or the power company can be asked to measure the power by means of special equipment. Where more than one pump is taking power through the master meter at the same time, the latter method is the only feasible one for testing each unit separately.

Securing Total Head

The total head in feet must first be secured. If the pressure gauge reads in pounds, convert to feet by multiplying the pounds of pressure by 2.31 [feet of water head giving one pound gauge pressure]. The suction will probably be expressed in inches of mercury. Convert this to feet of water head by multiplying by 1.13. Also measure the vertical distance between the center of the pressure gauge and the point of suction measurement. The total head then becomes the sum of the following:

Discharge pressure, in feet	xxx
Suction, in feet	xx
Vertical distance pressure gauge is above point of suction measurement, feet	x
Total Head in feet	xxx

Velocity head has been ignored, as it is a small factor for the relatively high heads which usually exist in water works operation.

If water is delivered to the pump under pressure, then the pump will be working against a head equal to the difference between the discharge pressure and the inlet pressure.

From the data secured during the test, determine the gallons delivered per kilowatt hour. As before, divide this by the theoretical value for the head against which the pump was operating. This gives the overall wire-to-water efficiency of the installation.

As an example, let us assume an installation where we secured the following test data:

Power input to motor	90.0	K.W.
Rate of discharge	51,840	gals. per hr.
Delivery per KWH	572	gals.
Pressure	146 lbs. =	337 ft.
Suction	15 ins. =	17 ft.
Difference in gauge elevation	1 ft. =	1 ft.
Total head		355 ft.

Theoretical discharge at 335 ft. head (see table) is $\left(\frac{318{,}200}{355}\right) = 897$ gals.

and

Overall efficiency (wire-to-water) is $\left(\frac{572}{897}\right) = 64\%$

If a suction gauge is not available, an approximation may be secured by measuring the vertical distance from the level of water in the clear well to the center of the pressure gauge, adding to this measured distance about two feet for loss in bends, etc.

What the Tests Reveal

Having shown the desirability of frequent tests and having presented a simple method for making them, it may now be interesting to discuss what these tests may be expected to show. In the first place, there have been great increases in the attainable efficiencies of centrifugal pumps within the past few years. Those of modern design may be expected to give up to the following overall (wire to water) efficiencies.

Capacity G.P.M.	Efficiencies Percent
200	58
400	63
600	68
800	71
1000	73
1500	75
3000	80
5000	82
Over 5000	85

It will be noted that the larger the pump the higher the efficiencies.

There will be variations from these figures depending upon the head and other conditions. Such are submitted only for the purpose of giving something with which to compare the efficiencies of existing installations. This is important, because it will often be found that older equipment may have retained its original efficiency and yet be so inefficient in comparison with modern equipment, now available, that it is decidedly not economical to keep it in operation. It will be worth while to check the present efficiency of every centrifugal pump now more than ten years old, to determine how great a reduction in power consumption can be secured by replacement with more efficient modern pumps. You may be surprised.

If an old 1,000 gpm pump, operating at an efficiency of 57%, is replaced with a new pump giving an overall efficiency of 73%

the same amount of water may be pumped with 22% less power. This means that both the demand rate and the power consumption through each step of the existing rate schedule would be decreased 22%. Such a reduction might prove enough to pay for the new installation in about one year's time. In order to get the gallons per KWH to be expected at any head, for any efficiency, it is only necessary ot determine theoretical gallons per KWH for that head and then to multiply this theoretical value by the expected efficiency. If the total pumpage in gallons is then divided by this expected pumpage per KWH the power consumption to be anticipated from the new installation will be secured. Similarly it is possible to determine the anticipated demand rate, which is often as important (if not more so) than is the total KWH consumption in determining the power bill to be expected from a new installation.

A Worthy Example

In the March, 1939, issue of WATER WORKS AND SEWERAGE an article by Messrs. Marshall and Rawlins of Charlotte, N. C., revealed graphically how the power costs were drastically cut at the local pumping station by replacing old equipment with new. These power costs, which had been running about $16.00 per million gallons were cut to about $7.50 per million gallons. This cut was the result of two definite and distinct improvements. In the first place the pumping main was paralleled with a new line. This resulted in reducing the former friction loss materially. This single betterment cut the power cost from $16.00 to $12.00 per million. Following this, the not very old (but less efficient) pumping units were replaced with modern efficient equipment. This investment, which might appear to the average municipal councilman a questionable expenditure, further reduced the pumping cost to $7.50 per million, representing a very notable day in and day out saving.

Measuring Output of Water

Table I has another use. Many plants, especially smaller ones, have no master meters. With the old displacement type pump it was possible to secure the approximate amount of water pumped by installing a pump stroke counter and multiplying the number of strokes by the discharge in gallons per stroke. If the pump were permitted to get into a state of disrepair, this measurement was apt to be in error, but if the pump were kept in good condition it was reasonably accurate. The method about to be outlined for obtaining the output of water from electrically operated centrifugal pumps has possibly a degree of accuracy comparable to the pump counter method.

From the efficiency curve furnished with the pump, determine the pump efficiency for the head under which the pump operates. The curve will show the pump efficiency only. The combined pump and motor efficiency, the so-called wire to water efficiency, will be about 90 per cent of the efficiency shown for the pump alone. From Table 1 secure the theoretical gallons per kilowatt hour for the head under which the pump is operated. Multiply this by the overall wire to water efficiency just secured. This gives the number of gallons per kilowatt hour the pump should deliver. Multiply this by the total number of kilowatt hours used over any given period of time and the result should be the number of gallons pumped over the sam period. To illustrate:

Assume a pump with an efficiency of 65 per cent operating at a total head of 200 ft. Then 90 per cent of 65 would give an overall wire to water efficiency of 58.5 per cent. If the installation were 100 per cent efficient, Table 1 indicates the discharge would be 1,592 gallons per kilowatt hour. With an overall efficiency of 58.5 per cent the discharge would be 1,592 $\times$ 58.5 per cent, or 931 gal. If the power consumption for the month be 20,000 kilowatt hours, then the total pumpage becomes 20,000 $\times$ 931 or 18,260,000 gal. for the month.

While this method of computing pumpage will not, as a rule, give results as satisfactory as those secured from a master meter, it does give a close approximation in instances where a master meter is not available.

In outlining the tests in this paper it has not been intended to supplant the more detailed methods used by professional engineers, but to make available to the average water works operator a method of checking which will give reasonably accurate results.

TERMINOLOGY IN PUMPING*

Static Head

Static Head is the vertical distance in feet between the free level of the source of supply and the point of free discharge, or to the level of the free surface of the discharge water.

Total Dynamic Head

Total Dynamic Head, as determined on test, where Suction Lift exists, is the reading of a mercury column connected to the suction nozzle of pump, plus the reading of a pressure gauge connected to discharge nozzle of pump, plus vertical distance between point of attachment of mercury column and center of gauge, plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where the instruments are attached, plus head of water resting on mercury column, if any.

Total Dynamic Head, as determined on test, where Suction Head exists, is the reading of a gauge attached to the discharge nozzle of pump, minus the reading of gauge connected to the suction nozzle of pump, plus or minus vertical distance between centers of gauges (depending on whether suction gauge is below or above discharge gauge), plus excess, if any, of Velocity Head of discharge over Velocity Head of suction as measured at points where instruments are attached.

Total Dynamic Discharge Head, is the Total Dynamic Head minus Dynamic Suction Lift, or plus Dynamic Suction Head.

Total Dynamic Head is the vertical distance between source of supply and point of discharge when pumping the required capacity, plus Velocity Head, plus friction and entrance losses.

*From "Hydraulic Data," an Ingersoll-Rand Hand-Book.

Suction Lift

Suction Lift exists where the source of supply is below the center of pump.

Static Suction Lift is the vertical distance from the free level of source of supply to center of pump.

Dynamic Suction Lift is the vertical distance from the source of supply, when pumping required capacity, to center of pump, plus Velocity Head, plus entrance, and friction losses; but not including internal pump losses.

Dynamic Suction Lift, as determined on test, is the reading of a mercury column connected to suction nozzle of pump, plus vertical distance between point of attachment of mercury column to center of pump, plus head of water resting on mercury column, if any.

Suction Head

Suction Head (sometimes called Head on Suction), exists when source of supply is above center of pump.

Static Suction Head is the vertical distance from the free level of the source of supply to center of pump.

Dynamic Suction Head is the vertical distance from the source of supply, when pumping at required capacity, to center of pump, minus Velocity Head, minus entrance, and friction losses; but not minus internal pump losses.

Dynamic Suction Head, as determined on test, is the reading of a gauge connected to suction nozzle of pump, minus vertical distance from center of gauge to center of line pump. Suction Head, after deducting the various losses, may be a negative quantity, in which case a condition equivalent to Suction Lift will prevail.

COMPUTING HORSEPOWER FROM REVOLVING WATT-HOUR METERS

A simple method of accurately measuring power consumption is of general interest to the owner or operator of any electrically driven pump. A periodical record of the power consumption, capacity of the pump, and the measurement of the pumping level assists in maintaining operation at maximum efficiency and gives an indication as to the proper time for reconditioning or modernizing the installation.

The power consumption is measured by the Watt-Hour Meter, usually located on the switchboard in the pump house adjacent to the motor. Large units require current and/or potential transformers, so that the watt-hour meter reading must be multiplied by the ratio of these transformers to obtain the correct measurement of power consumption of the motor.

A motor which draws 200 amp. at 440 volts may be metered through current transformers rate 200 amp. primary and 5 amp. secondary, so that 5 amp. would pass through the watt-hour meter. No potential transformers being used, the watt-hour meter reading, multiplied by the ratio of 200 to 5, would give the amount of power in the main circuit.

Asssuming that a motor draws 600 amp. at 2300 volts, potential as well as current transformers are required. If the ratio is 60 to 5 amp. on the current, and 2300 to 115 on the potential transformers, the watt-hour meter reading multiplied by the ratio of 60 to 5 and in addition, by the ratio of 2300 to 115, will give a true measure of the power consumption in the main circuit. The correct ratio is usually stamped on a brass nameplate attached to the transformer.

Disk constants and multipliers for practically all modern watt-hour meters now in use for single and three phase, 110-220-440 volts are shown in the chart below.

Use of Chart

First determine the make, type, volts and amp. of the meter. If no current or potential transformers are used, refer to the chart and determine M value for the meter. The M × r.p.m. of disk = hp. input to motor for example, a meter, G.E., type D-3, 220 volt, 15 amp., K = 4.0, M = .3217, number of revolutions of disk in one minute = 20. Then .3217 × 20 = 6.434 h.p. input to motor.

As another example consider an installation where current transformers having a ratio of 20 to 1 are used. Meter, Westinghouse type OA, 220 volt, 5 amp., K = 1⅓, M = .1027, number of revolutions of disk in one minute = 21. Then, .1072 × 21 × 20 = 45.02 h.p. input to motor.

Disk constants K are included in the accompanying chart because occasionally the manufacturer's nameplate has been removed, in which event the constant K is marked on the meter. To determine the M value in such cases, find a K in the table corresponding to that on the meter in question. The M applying will be the one adjacent to and on the right of this K.

Definitions:

K—A constant which represents the number of watt-hours passed through the meter while the disk makes one revolution.

M—A factor which, when multiplied by the number of revolutions of the disk, in one minute, gives h.p. input to motor.

Mathematically, $M = \frac{K \times 60}{746}$

The h.p. values expressed above relate to input to motor. The rating of motors is in terms of h.p. output. Therefore, the h.p. output or brake h.p. is determined by multiplying the h.p. input by the motor efficiency, which can be obtained from the motor manufacturer.

Chart of Constants and Multipliers

For Use in Determining KW Input, HP Input or BHP from Revolutions of Watthour Meter Disks

110 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.3	.0241	.25	.0201	.3	.0241	.6	.0483	5/24	.0168	⅓	.0268
10	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
15	1.0	.0804	.75	.0603	.9	.0724	1.8	.1448	5/8	.0503	1	.0804
25	1.5	.1206	1.25	.1005	1.5	.1206	3.0	.2413	2 5/24	.0838	1⅔	.1340
50	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681

220 Volt—Single Phase

Amp.	General Electric 1		General Electric 1-10		General Electric 1-14		General Electric 1-16		Sangamo H		Westinghouse B, C, OA, OB	
	K	M	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.5	.0402	.6	.0483	1.2	.0965	5/12	.0335	⅔	.0536
10	1.25	.1005	1.0	.0804	1.2	.0965	2.4	.1930	5/6	.0670	1⅓	.1072
15	2.0	.1609	1.5	.1206	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	2.5	.2011	3.0	.2413	6.0	.4826	2 1/12	.1676	3⅓	.2681
50	6.0	.4826	5.0	.4021	6.0	.4826	12.0	.9651	4 1/6	.3351	6⅔	.5362

110 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	.6	.0483	.6	.0483	1.2	.0965	5/12	.0335	2/3	.0536
10	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
15	2.0	.1609	1.8	.1448	3.6	.2895	1 1/4	.1005	2	.1609
25	3.0	.2413	3.0	.2413	6.0	.4826	2 1/12	.1676	3 1/3	.2681
50	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362

(*Continued on next page*)

220 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	1.25	.1005	1.2	.0965	2.4	.1930	5/6	.0670	1 1/3	.1072
10	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
15	4.0	.3217	3.6	.2895	7.2	.5791	2 1/2	.2011	4	.3217
25	6.0	.4826	6.0	.4826	12.0	.9651	4 1/6	.3351	6 2/3	.5362
50	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072

440 Volt—Three Phase

Amp.	General Electric D-3		General Electric D-6 & D-7		General Electric D-14		Sangamo H		Westinghouse C, OA, OB, RO.	
	K	M	K	M	K	M	K	M	K	M
5	2.5	.2011	2.4	.1930	4.8	.3861	1 2/3	.1340	2 2/3	.2145
10	5.0	.4021	4.8	.3861	9.6	.7721	3 1/3	.2681	5 1/3	.4289
15	7.5	.6032	7.2	.5791	14.4	1.158	5	.4021	8	.6434
25	12.5	1.005	12.0	.9651	24.0	1.930	8 1/3	.6702	13 1/3	1.072
50	25.0	2.011	24.0	1.930	48.0	3.861	16 2/3	1.340	26 2/3	2.145

hp. Input = "M" × Revolutions per minute of Disk

hp. Input = "K" × Number of Revolutions × 3600.

Sec. × 746

Important—Where instrument transformers are used, be sure that figure computed from revolutions of disk and table be multiplied by ratio of instrument transformers.

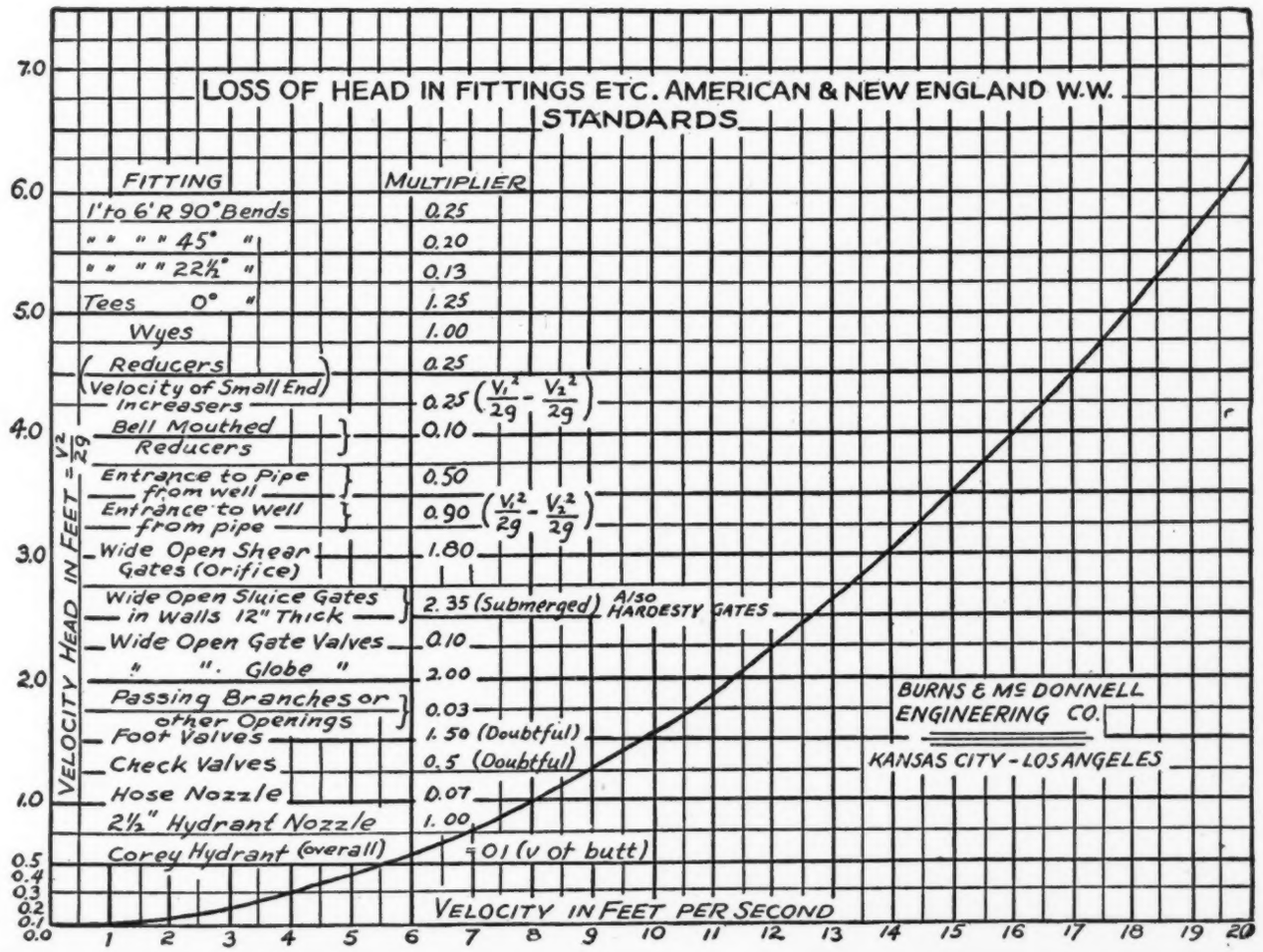
(From Byron-Jackson Bulletin, "Deep-Well Turbine Pumps.")

Loss of Head Through Valves and Fittings

(Burns and McDonnell)

To determine loss of head—Assume flow (Q) to be 5 cu. ft. sec. through a fitting of 12 inch diameter. From Q—AV the velocity (V) = 6.4 ft. per sec. From the chart, velocity head $\frac{V^2}{2g} = 0.7$ ft. Applied to 90 degree bend head loss is $0.25 \times 0.7 = 0.18$ ft. For a tee $1.25 \times .7 = 0.87$ ft.

(Note—Recent correspondence with the producers of this chart cites valves for check valves far in excess of the 0.5 indicated.—*Ed.*)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FITTING
MULTIPLIER
1' to 6' R 90° Bends 0.25
" " " 45° " 0.20
" " " 22½° " 0.13
Tees 0° " 1.25
Wyes 1.00
Reducers 0.25
(Velocity of Small End)
Increasers 0.25 (V1²/2g - V2²/2g)
Bell Mouthed Reducers 0.10
Entrance to Pipe from well 0.50
Entrance to well from pipe 0.90 (V1²/2g - V2²/2g)
Wide Open Shear Gates (Orifice) 1.80
Wide Open Sluice Gates in Walls 12" Thick 2.35 (Submerged) Also HARDESTY GATES
Wide Open Gate Valves 0.10
" " Globe " 2.00
Passing Branches or other Openings 0.03
Foot Valves 1.50 (Doubtful)
Check Valves 0.5 (Doubtful)
Hose Nozzle 0.07
2½" Hydrant Nozzle 1.00
Corey Hydrant (overall) = 0.1 (v of butt)
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FOR YOUR WATER DISTRIBUTION SYSTEMS - - -

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You save all ways when you install Transite Pressure Pipe—for in addition to low first cost and rapid, economical installation—it is remarkably resistant to all the destructive agencies encountered in service. Being non-metallic, Transite is entirely unaffected by electrolysis and tuberculation—the internal corrosion that cuts down flow rates and increases pumping costs—and it is highly resistant to all forms of corrosion.

Manufactured in a wide range of sizes—from 2 to 36 inches inclusive—and in pressure classes of 50, 100, 150 and 200 lbs., it is composed of an intimate mixture of asbestos fibres and cement, formed under tremendous pressure, on a polished steel mandrel, into a tough, dense, homogeneous structure of great strength and uniformity.

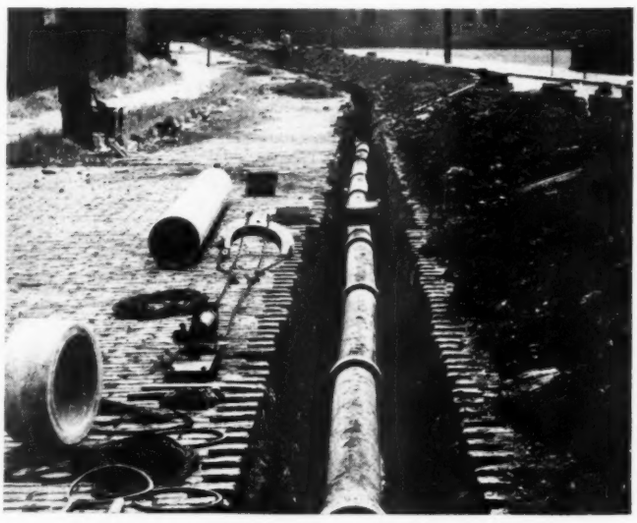
TRANSITE CANNOT TUBERCULATE

The smooth interior surface imparted to Transite Pipe by the mandrel on which it is made offers minimum resistance to the flow of water. Numerous tests have proved that the conservative minimum flow coefficient for Transite lines in service is C=140. Some outstanding Water Works authorities report coefficient values on asbestos-cement pipe from 142 to as high as 165.

In 1935, the Pitometer Company conducted a series of tests to establish the flow coefficient on a 14" Transite Pipe line that had been installed in 1932.

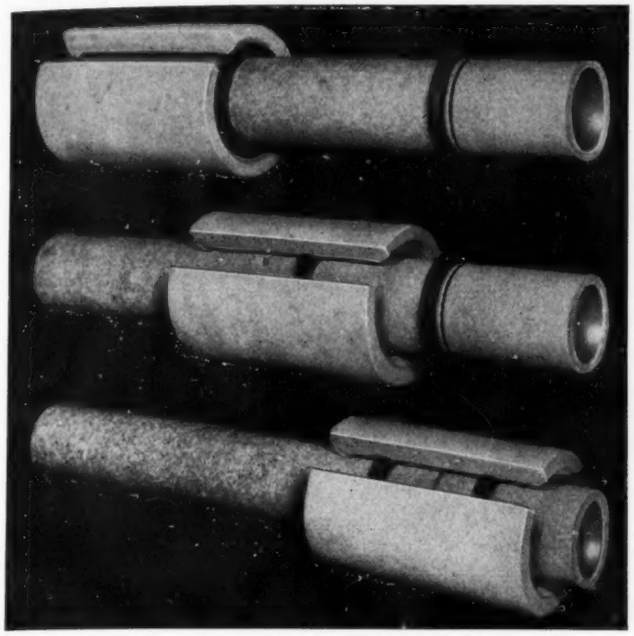
The results of the tests were summarized by the Pitometer Company in the following conclusion to their report: "From a study of the data, we believe that an average coefficient of C=145 is very nearly correct for this pipe."

Because it is immune to tuberculation, wherever used, Transite Pipe assures an abundant supply of water through the years with low pumping costs.



Transite's remarkable resistance to all forms of corrosion, due to its asbestos-cement composition, assures long life and low maintenance costs.

JOHNS-MANVILLE



In the above illustration of the Simplex Coupling, the Transite sleeve has been cut to show how the rubber rings are compressed between the sleeve and the pipe. Top: rings and sleeve at start of operation. Center: sleeve pulled over one ring. Below: final position, sleeve centered over joint.

Because Transite Pipe is made of asbestos and cement, this high coefficient value can *never be reduced by tuberculation!* The interior wall remains smooth indefinitely—its initial high delivery capacity is permanently unaffected by this costly economic evil. This assures virtual freedom from excessive pumping costs, reduced pressures and the expense and inconvenience of periodic cleaning.

HIGHLY RESISTANT TO CORROSION

One of the important advantages of Transite's asbestos-cement composition and unusually low free-lime content is its high resistance to external corrosion. Practically unaffected by all active agents in the strength encountered underground, Transite assures large economies in maintenance even when laid under conditions that rapidly destroy other materials.

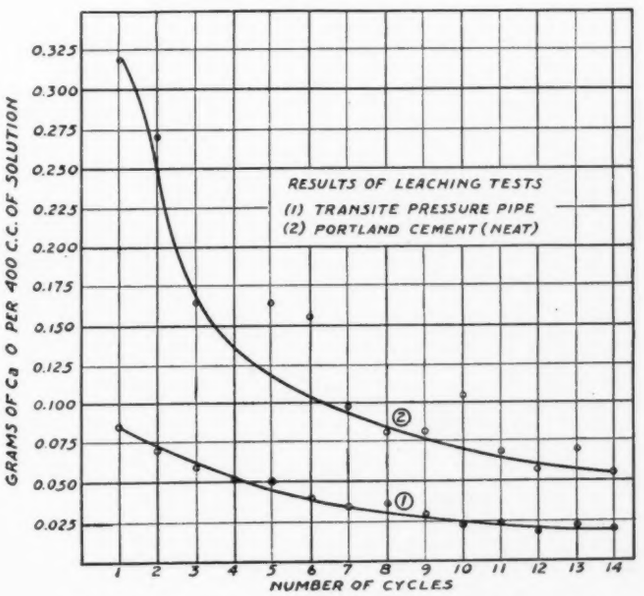
Although there is a certain amount of free lime in ordinary neat cement which may be affected by corrosion, in Transite virtually all this free lime is converted into insoluble silicates by a special curing process—thereby greatly increasing its natural chemical stability.

Thousands of installations of asbestos-cement pipe all over the world, laid in all kinds of soil and carrying all types of water, attest to Transite's exceptional resistance to corrosion, its low maintenance cost and permanent efficiency.

LOWER INSTALLATION COSTS

Savings in installation costs with Transite Pipe begin at the very outset. Because of its long 13-foot lengths, relatively light weight and speed of assembly, it is rapidly, economically installed, even by unskilled workmen. More footage may be carried per truck load, fewer men are required for every handling operation and no mechanical equipment is required except for the very largest sizes.

The ease and speed of assembly of the Simplex Coupling used in Transite Pressure Pipe lines is one of the major factors contributing to installation savings. Consisting of a Transite sleeve and two rubber rings, they are easily assembled in much less time than that required by ordinary types of joints. It is not necessary to maintain heating equipment at various points on the job, for the Simplex Couplings are assembled cold



The chart above represents a series of leaching cycles for both pulverized Transite Pipe and neat cement. The small amount of free lime extracted from Transite indicates that for all practical purposes it may be considered insoluble—one of the major factors responsible for its unusual resistance to soil corrosion.

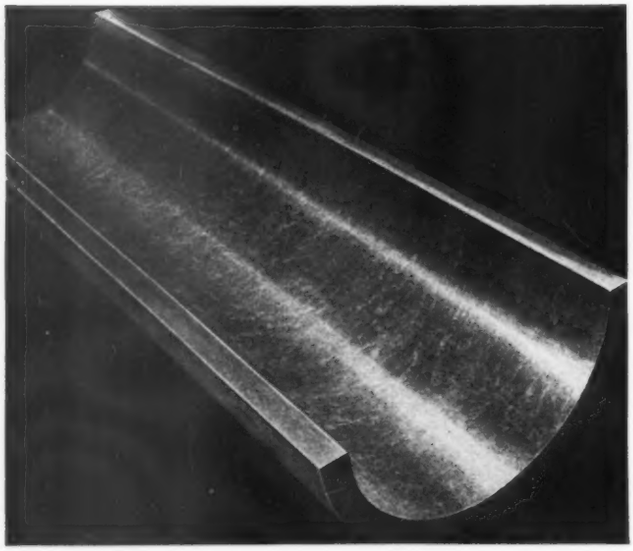
just as they are received from the factory—a simple hydraulic coupling puller is the only tool required.

Not only do these couplings permit faster installation and tight joints, but they also provide a desirable flexibility in the line to accommodate ground movement and prevent breakage. Furthermore these tight, flexible joints permit laying the pipe on long curves without the use of special fittings.

Because of the tough, dense structure of Transite Pipe, it may be drilled and tapped perfectly with standard tapping tools and methods. The deep, clean threads are strong and firm. They provide perfect seating for threads on corporation stops and eliminate leakage at these points.

LOWER MAINTENANCE COSTS

Because Transite Pipe is absolutely immune to tuberculation and electrolysis and highly resistant to all forms of soil corrosion, it provides the best assurance of permanent freedom from cleaning expense, shutdowns and costly renewals. Furthermore, Simplex Couplings minimize underground leakage and prevent the breaks in mains due to undermining of pipe by joint leakage.



Because Transite is non-metallic, its original smooth interior surface remains permanently unaffected by the destructive, choking effects of tuberculation.

The absence of large bell holes at joints permits the use of narrow, less expensive trenching as is well illustrated by this installation of 6" Transite Pipe.

LOWER PUMPING COSTS

Added to the substantial savings in installation and maintenance are the even greater savings in pumping costs, due to Transite Pipe's initial smooth interior surface and freedom from tuberculation, plus the extra advantage of tight joints that prevent wasted water and reduced pressure caused by leakage.

Yet, with all these points of superiority, Transite Pipe costs no more, installed, than other types of water pipe.

WRITE FOR COMPLETE DETAILS

For further information on how this modern, permanent water carrier can save you money through the years, write for the free, 36-page, Transite Pressure Pipe Brochure, TR-11A. In addition to complete details on how Transite Pipe will cut your installation, maintenance and operating costs, this illustrated brochure contains excerpts from the Underwriters' Laboratories Report on Transite Pipe, the unbiased opinions of scores of users throughout the country and a wealth of other information vitally important to everyone interested in the more efficient operation of water distribution systems. Ask, also, for the interesting set of Hydraulic Tables based on Hazen and Williams figures, which demonstrate the effect of tuberculation on pumping costs through five to twenty years of service.

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AND IN YOUR SEWAGE DISPOSAL SYSTEMS - - -

TRANSITE SEWER PIPE will increase the efficiency of your system and reduce expense to an absolute minimum!

Manufactured under extreme pressure in the same manner as Transite Pressure Pipe, and made of the same permanent, non-metallic minerals—asbestos fibre and cement—Transite Sewer Pipe is establishing an enviable record for economy and efficiency in sewage disposal systems. Furnished in a wide range of sizes—from 4 to 36 inches inclusive, and in both single and double strength, its many outstanding advantages over ordinary sewer pipe set it apart as being the ideal material for this service.

LONG LENGTHS, LIGHT WEIGHT REDUCE INSTALLATION COSTS

The long 13-ft. sections in which Transite is furnished eliminate the difficulties in installation and maintenance common to ordinary short length sewer pipe. Strong, durable, yet comparatively light in weight, these long sections cut handling costs to a minimum. More footage may be carried per truck load to the trench, fewer men are required to install the pipe and no mechanical equipment is needed except for the very largest sizes. These long lengths reduce the number of joints in the line (only 1/3 to ¼ as many joints as with ordinary short length pipe) and thus save considerable time and labor. In addition, long lengths are more easily laid to a line and resist the tendency to slip out of alignment; therefore, they greatly facilitate laying the pipe to an accurate grade.

Transite, the corrosion-resistant, asbestos-cement sewer pipe, answers every requirement of efficient sewerage service. Its long 13-ft. lengths make laying to exact grades a quicker and more accurate job. And the tight joints employed minimize infiltration.

TIGHT SLEEVE JOINTS REDUCE INFILTRATION

The poured sleeve joints used in Transite gravity flow lines reduce infiltration to a minimum and with this type of joint there is no bell to break off—the sleeve extends over both lengths of pipe, providing twice the flexibility possible with other types of joints.

The ends of all pipe and the inside of all joint sleeves are *double*-primed at the factory with a specially developed primer that assures greatest adhesion between pipe and compound.

The jointing compound used is the highest quality, unfilled asphalt. It is strong, flexible and easily poured. This compound provides strong, tight joints that minimize root growth, and the infiltration of ground water and silt that cuts the sewage-carrying capacity of ordinary pipe.

The Simplex Couplings used on Transite force mains provide tight, rapidly installed joints that reduce leakage to an absolute minimum.

REDUCED MAINTENANCE COSTS

Transite's unusual resistance to all types of corrosion—inside, outside and all the way through—has been proved by a large number of installations serving under a wide variety of conditions. It is virtually unaffected by the action of hydrogen-sulphide gas and other destructive agencies found in sewage. In Transite, practically all of the free lime found in ordinary cement products is converted into insoluble silicates, thereby greatly increasing the natural permanence and corrosion-resistance of this asbestos-cement pipe. Its smooth interior surface gives a higher sewage flow and minimizes the labor cost of flushing.

For complete details about this modern sewer pipe write to Johns-Manville, 22 E. 40th Street, New York, N. Y.

JOHNS-MANVILLE JM PRODUCTS

PIPE LINE FRICTION COEFFICIENTS

*A Summary of the Findings of the Committee on Pipe Line Friction Coefficients**

The voluminous report embracing data collected and compiled by the above committee has been printed in the September, 1935, *Journal* of the New England Water Works Association, and is available in the form of reprints.

A summary of the scope of this report and the conclusions presented therein are reviewed in the following abstract, prepared by E. T. Killam, chairman of the Committee.

The general conclusions drawn from the data submitted to the Committee are as follows:

1. The average *actual* loss in capacity of tar-coated cast-iron pipe after 30 years of service, based on a total of 473 tests in 19 different systems, was 52 per cent.

The loss *predicted* in the Williams-Hazen tables for mains of similar age and diameter (average 20.5 in.) and for "average soft unfiltered river water" is 32.3 per cent.

2. Based upon the data available to the Committee, the Williams-Hazen age-coefficient relation is applicable primarily to large-diameter mains carrying relatively inactive water.

3. For small-diameter mains carrying active water, the actual *loss* after 30 years may be twice the Williams-Hazen *predicted* loss.

4. Other factors being equal the data show marked correlation between pH value of water carried and rate of capacity loss, average conditions reported indicating for supplies with a pH value of 6.5, twice the loss observed in supplies with a pH value of 8.0.

Scope of Report

The principal objective of the report was the presentation of heretofore unpublished data upon friction coefficients of tar-coated cast iron pipe, with particular reference to the age-coefficient relation for this type of pipe, and the effect of water quality upon rate of capacity loss.

The report also contains sections dealing with various remedial measures for reducing and preventing loss of capacity, including discussions of coefficients of cement and bitumastic-enamel linings; methods of lining pipe in place; corrective treatment of the water carried, and pipe cleaning.

Certain other subjects not involved in the question of discharge coefficients of tar-coated cast-iron pipe, but falling within the general scope of the subject of "Pipe Line Friction Coefficients," have been presented in the form of appendices, in order that this additional information might be made readily available in a single report.

Precision

The Committee has endeavored to compile mass data of reasonable precision; obviously, the widely varying conditions found, and the many factors involved, could not be generalized upon any other basis. Accordingly, while the collection of data was in no way restricted to sources affording "laboratory" precision, the material presented includes only such data as have been considered to fall within limits of reasonable precision set by the Committee.

This policy of precision applies particularly to the presentation of various "trend curves," which is the designation adopted for expressing the age-coefficient relation. These "trend curves" in which values of C have been plotted against the age of the pipe in years, have been presented only in cases for which numerous tests of reasonable accuracy were available.

In considering these trend curves it should be emphasized that the results represent actual field tests and accordingly include all incidental losses due to irregular line or grade, and due to fittings or special castings.

Use of Williams-Hazen Coefficient "C"

The Williams-Hazen formula has been used throughout the report for the determination of coefficient values, and all values of C refer to the Williams-Hazen coefficient in the following formula:

$$v = Cr^{0.63} s^{0.54} 0.001^{-0.04}$$

v = Velocity in feet per second
r = Hydraulic Radius in feet
s = Hydraulic slope in feet per foot
C = The Williams-Hazen Coefficient

In translating values of C to equivalent capacity loss, it is convenient to bear in mind that capacity is directly proportionate to the value of C. With slope and diameter fixed, a drop in the value of C from 130 to 65 consequently involves an equivalent capacity loss of 50 per cent.

Coefficients of Tar-Coated C. I. Pipe

Tar-coated cast iron pipe has been more widely used in water works practice than any other type of pipe, and a discussion of coefficient values with this type of pipe was accordingly selected for the first and principal subject of the report.

In considering the existing condition of old pipe, and attempting to determine the loss of capacity with age, selection of a value of C for new pipe becomes a fundamentally important assumption. The values of C for new tar-coated cast iron pipe adopted in the report are as follows:

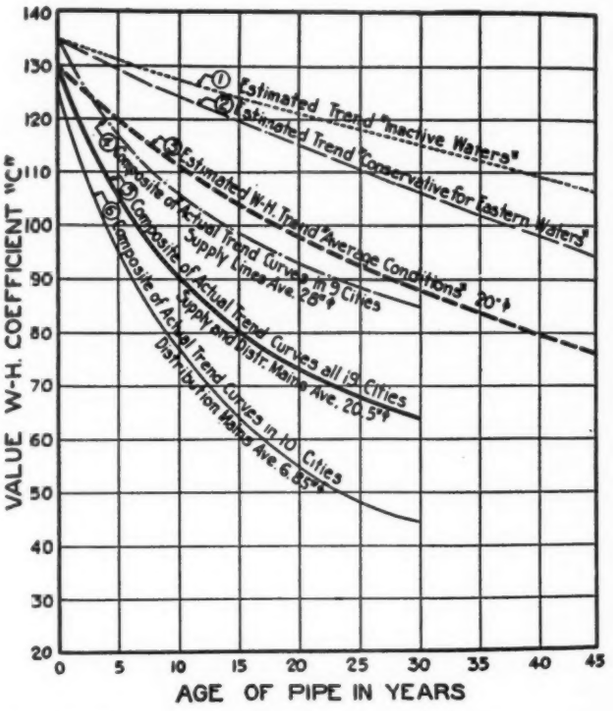

Fig. 1.—Summary of estimated and actual trends of Age-Coefficient Relation for Tar-Coated Cast-Iron Pipe.

Curves 1 and 2 are based on data for steel pipe (U. S. Dept. of Agriculture, Bull. 150, 1930).

Curve 3 is based on the Williams-Hazen Tables for average soft unfiltered river water.

Curve 4 is a composite for supply and transmission lines 16 in. or larger in diameter.

Curve 5 is a composite of Curves 4 and 6. Composite curves are based on arithmetic averages.

Curve 6 is a composite for distribution mains less than 16 in. in diameter.

For supply and transmission mains 16 inch and larger in diameter ..... C = 135

For distribution mains less than 16 inch in diameter, with allowance for Ts, valves, bends, corporation cocks, or other specials involving friction loss..... C = 125

Variations possibly approaching 10 per cent higher or lower may be found, but the foregoing represent the average values from data available to the Committee.

* Presented before the New England Water Works Association September 17, 1935.

The most widely used basis for estimating the probable loss of capacity of tar-coated cast iron pipe with age, (other than the convenient, though inadequate, assumption that C = 100) is the age-coefficient relation shown in the column headings of the Williams-Hazen tables.

These Williams-Hazen predicted age coefficient relations—or trends of C—accordingly form a convenient basis for comparison with actual trends computed from the data submitted to the Committee.

The data compiled on actual trends of the age-coefficient relation for tar-coated C. I. pipe includes a total of 473 tests in 19 different cities. These data, results of which have not heretofore been published, have been classified and are presented in the form of trend curves.

These trend curves, as in the assumption of values for new pipe, have been segregated into two major classifications, namely, for supply and transmission mains 16-inch and over in diameter, and for distribution mains less than 16-inch in diameter.

Further classification has been made by grouping trend curves of similar type or source of supply; or according to general location or type of supply.

Summary of Data on Actual Capacity Loss in Tar-Coated C. I. Pipe

The data on actual loss of capacity in tar-coated C. I. mains may be briefly summarized, as follows:

Supply lines in nine cities showed a loss after 30 years of 37 per cent as compared with a predicted Williams-Hazen loss of 30.8 per cent.

Distribution mains in ten cities showed an actual loss in 30 years of 64 per cent as compared with a Williams-Hazen predicted loss of only 37 per cent.

Average results of 473 tests in 19 individual systems, including sizes ranging generally from 6-inch to 48-inch in diameter with a weighted average size (according to numbers of tests of each size) of 20.5 inches, showed an actual loss in 30 years of 51.5 per cent, as compared with a predicted loss of 32.3 per cent for pipe of the same diameter.

These data accordingly indicate that the Williams-Hazen predicted trends are applicable primarily to large diameter mains carrying relatively inactive water—and do not represent "average conditions."

Quality of Supply and Its Effect on Capacity Loss

The wide variation in rate of capacity loss in different systems and the appreciable extent to which this loss progresses in a relatively short time in many systems, directs attention to probable causes of such loss. In collecting data, the Committee has accordingly attempted to consider the quality of supply and its effect upon rate of capacity loss.

Alkalinity and carbon dioxide have an important effect on rate of capacity loss. Because of the inter-relation between alkalinity, carbon dioxide, and pH, this effect may be measured against the pH value alone.

The relation of pH to rate of capacity loss has been illustrated in the report by a diagram on which the per cent of capacity loss in a fixed period, (30 years) in various supplies, has been plotted directly against the pH of the supply.

The pronounced relation indicated by the data, showing the marked effect of pH on the relative rate of loss, may be summarized as follows:

pH Value of Supply	Approximate Average Per Cent Capacity Loss in Tar-Coated C. I. Pipe (In 30 Years)
8.0	30
7.5	35
7.0	45
6.5	60
6.0	85

Capacity Loss in Tar-Coated C. I. Pipe Due to Special Causes Other Than Tuberculation

Although tuberculation is most frequently the cause of loss of capacity in tar-coated cast iron mains, certain cases included in the Committee data afford examples of capacity loss due to other special causes. In some instances the resulting trends of capacity loss are quite similar to cases where loss was caused by tuberculation. Among special causes of capacity loss are: incrustation, due to the precipitation on the pipe either of natural mineral content in the water, or of lime after water treatment; slime or fungus growth; and silting.

Coefficient Values of Cement-Lined Pipe

In addition to the main section of the report dealing with friction coefficients of tar-coated cast iron pipe, a number of related subjects involved in the general question of friction coefficients, are discussed.

Accordingly a second section of the report is devoted to coefficient values of cement-lined pipe.

The development of the centrifugal method of applying cement lining has inevitably resulted in the increased use of this type of lining as a method of preventing capacity loss. Available data upon the values of C for cement-lined pipe are limited in scope and widely scattered in the literature. Accordingly, all available data have been compiled and presented in order that they may be made more readily available.

The Committee data indicates that the average value of C for new pipe, 4-inch to 24-inch in diameter with cement lining centrifugally applied, is 134, based on nominal diameter; and 150 based on actual net diameter.

These data also indicate that at least for mains 24-inch or less in diameter, the effect of lining thickness on diameter encroachment is sufficient to warrant considering values of C based both on nominal and on actual net diameter.

Other tests on pipe with cement lining not applied by centrifugal methods showed the following values: For pipe with natural or Rosendale cement lining tested both when new and at the end of approximately a 10-year period, C = 136; for old style cement lined wrought-iron pipe 12-inch and 14-inch diameter, after 41 years of service, C = 104.

Available data relative to the value of cement lining in maintaining hydraulic capacity are extremely limited in scope. One line tested when new and again after six years of service showed no loss of capacity. Another line tested when new and after 1, 7, and 10 years of service, also showed no tendency to decrease in carrying capacity with age. The data indicate that cement lining can be credited with a sustained capacity not attainable with tar-coating.

Coefficient Values of Pipe with Bitumastic Enamel Lining Centrifugally Applied

A third section of the report is devoted to a discussion of coefficient values with Bitumastic enamel lining applied by the centrifugal method. As in the case of cement lining, development of centrifugal methods of application have resulted in a greatly increased use of this type of lining to control capacity loss. Due to limited data available, results of all of the tests which have been conducted, together with a discussion of test methods, have been presented in the report. Results available include tests on 10, 12, and 20-inch cast iron pipe; and on 30-inch steel pipe.

The data indicate that coefficient values for new supply and transmission mains 16-inch in diameter and larger, with bitumastic enamel lining (centrifugally applied) may vary from C = 145 to C = 160 with an average value of C = 155; all based on nominal diameter.

These data also indicate that coefficient values for distribution mains less than 16-inch in diameter, with this style of lining, may vary from C = 140 to C = 150 with an average value of C = 145.

Bitumastic enamel lining is ordinarily applied with a thickness of only 3/32-inch. Encroachment on diameter is accordingly small, as compared with other types of lining.

The first application of this type of lining was in 1931, and accordingly no data is available relative to its effectiveness in sustaining hydraulic capacity. The longest service period reported is two years, and the results of this test indicate no loss. The same material applied by the hand-brush method has been widely used for many years, and visual inspection of large pipe thus lined indicates that at least within periods of 16 years no apparent deterioration has occurred.

Application of Linings to Mains in Place

While the foregoing methods of lining pipe provide methods of preventing or retarding capacity loss on new work, the question of restoration of capacity of many miles of mains already in place is of no less importance. The high cost of abandonment and duplication of existing mains, particularly under permanent pavements has directed attention to possible

methods of reconditioning or lining existing mains in place, subsequent to cleaning.

Reference is made in one section of the report to available methods of lining mains in place.

Two methods have been devised in England for lining small diameter mains; the "Eric" process by which a bitumen lining is deposited electrically; and the Tate process, by which a cement-mortar lining is deposited in the pipe.

In this country, two methods have been developed for the reconditioning and lining of large diameter mains. On pipe lines sufficiently large to permit entry, the lines may be carefully cleaned and then treated with an application of hot bitumastic lining. A second method, which has recently been developed, involves the centrifugal application of a cement lining to large diameter mains in place. The lining is whirled into place by centrifugal force from a high speed centrifugal jet.

Corrective Treatment

In addition to the use of protective linings, chemical treatment of the water for reduction of corrosion has been adopted in recent years to abate the problem of capacity loss, and mention is made in the report, of some of the more important phases of corrective treatment.

Lime, sodium hydroxide and soda ash are among the alkalies used to reduce corrosion.

If water is maintained saturated with respect to calcium carbonate, it will be practically non-corrosive to iron.

In maintaining adequate corrective treatment it is essential to maintain the treated water at or very near the saturation point, for super-saturation results in excessive deposits, and under-saturation causes the destruction of the needed protective film.

In corrective treatment, consideration must be given to the fact that the pH value at which saturation equilibrium occurs, varies with the characteristics of the water treated.

The calcium bi-carbonate, (alkalinity) of the water and its magnesium content are the most important factors. Saturation occurs at a pH of only 7.2 with an alkalinity of 190 ppm., whereas with water containing only 15 ppm. alkalinity, the pH must be raised to 9.3.

Accordingly, in planning corrective treatment, particular attention must be given to the characteristics of the water. The fact that a pH of 8.0 for example, is successful in controlling corrosion in one system, is no criterion as to the pH that must be maintained with another supply.

Restoration of Capacity of Unlined Cast Iron Mains by Cleaning

Cleaning of cast iron mains to restore capacity is an important consideration in the problem of capacity loss.

Two important phases of this question are discussed in the report: First, the immediate increase in coefficient values and consequent increase in capacity obtainable by cleaning. Second, the rate of capacity loss subsequent to cleaning, or otherwise expressed, the maintenance of capacity after cleaning.

Data available to the Committee indicate that cleaning will ordinarily retsore mains to approximately 85 per cent of their original capacity. The average value of C in 24 tests was 39 before cleaning, and 104 after cleaning. If it is assumed that the value of C for new pipe was 125, the percentage of original capacity was accordingly 31 per cent before, and 83 per cent after cleaning.

The period through which the relatively high capacity obtained immediately after cleaning is sustained, is subject to wide variations in individual cases. Some instances, particularly with small mains, are recorded, wherein the results of cleaning do not last more than four or five months. In other instances the capacity is maintained at reasonably high values for substantial periods of time.

Summary of Appendices

All of the foregoing subjects deal directly with coefficients with tar-coated cast iron pipe, with the effect of age on coefficient values, or with alternate methods of retarding or preventing capacity loss.

Certain other subjects, while not directly concerned with these questions are, nevertheless, involved in the general questions of pipe-line friction coefficients. Among these related subjects are coefficient values of steel and of concrete pipe.

Coefficient Values of Steel Pipe

A discussion of coefficient values for steel pipe, due to the wide difference in interior surface with various methods of pipe construction, necessitates a definition of the several classes of steel pipe.

The classification of alternate types by Scobey in Bulletin 150 of the U. S. Dept. of Agriculture, provides a convenient standard for summarizing the values of C for various types of steel pipe when new.

The ordinary average values of Williams-Hazen C for various classes of new steel pipe may be summarized as follows:

Corrugated pipe	60
Spiral riveted flow against laps	100
Spiral riveted flow with laps	110
Full riveted	115
Girth riveted	130
Continuous interior pipe	139

Coefficient Values of Concrete Pipe

Available data on concrete pipe indicate an extremely wide range in values of C, with instances of values as low as $C = 85$ and as high as $C = 152$. This wide range may be attributed not only to variation in surface texture or roughness of the pipe, but also to the relative uniformity of the pipe bore or, in other words, the presence or absence of undulations on the interior surface.

With these wide variations, particular care must be exercised in selecting values of C for concrete pipe.

Data available to the Committee indicate that the average value of C for the best grade, new, and large diameter precast reinforced concrete pipe, carefully manufactured, may be assumed to approximate $C = 150$. On the other hand unless rigid metal forms, rich mix of concrete, careful curing and best workmanship throughout are employed, considerably lower values must be anticipated.

Values of C for concrete pipe of different classes and different methods of manufacture are presented in the report, these values being taken largely from a comprehensive paper by Fred C. Scobey, on this subject.

Tests on concrete pipe after substantial periods of service indicate that under normal conditions the initial capacity is relatively permanent.

Summary

The vast financial loss resulting from rapid capacity reduction of pipe systems indicated by the data upon which the report is based, is a matter of major importance to the water works industry. It is believed of sufficient moment to warrant the determination, in each system, of the rate and cause of loss; as a basis for the adoption of the best preventive measures whether they are provision of permanent linings or corrective treatment of the supply.

Upon the basis of the average data on tar-coated cast iron pipe, it is found that in 19 cities the average value of C after 30 years' service was 64, as compared with a value of 88 predicted in the Williams-Hazen tables. Otherwise expressed the value of C dropped to 88 after only 11 years of service instead of after a predicted period of 30 years.

Furthermore, these average figures involve relatively large mains (20.5 inches average diameter). In 8 out of 10 systems the value of C for distribution mains after 30 years' service was less than 50—involving a consequent loss of capacity of from 61.6 to 84 per cent, as compared with a predicted loss of 37.5 per cent.

The trend curves presented in the report, illustrate a wide range of loss of capacity in various systems, and the very considerable magnitude to which such loss develops within a comparatively short period in relation to the structural life of the pipe. It is hoped that these curves will serve to interest members of this and other associations in conducting and recording tests, in order that more selective numerical data may be ultimately made available to the profession.

Elson T. Killam, Chairman; Frank A. Barbour, W. W. Brush, Laurence C. Hough, Charles W. Sherman.

GENERAL PAINT CORPORATION—Hill, Hubbell & Co. Division

Lining and Coating STEEL PIPE for Water Mains and Supply Lines

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BITURINE AKWALINE Lining Prevents Corrosion, Tuberculation, Incrustation and assures CAPACITY FLOW

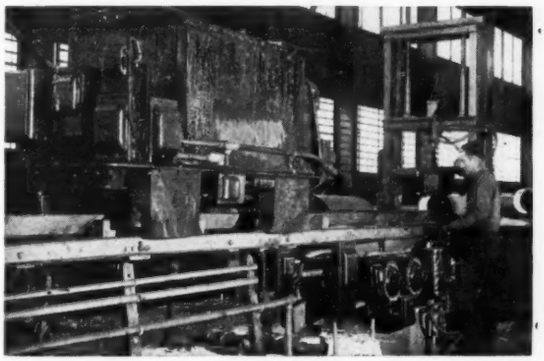
The use of STEEL PIPE for water supply lines is not new! For more than half a century, "big inch" steel pipe has been used—carrying water to many large cities in the United States.

Here are a few of the many inherent and unquestioned supremacies of STEEL PIPE:

Highest bursting strength	Least leakage
Greatest flexibility, ductility	Lowest laying costs
Longest lengths	Greatest, enduring capacity
Fewest joints	Lowest pumping costs

The HILL-HUBBELL "factory process" of applying linings to the more widely used sizes of STEEL PIPE makes it possible for the smaller community, also, to have the many advantages of STEEL PIPE. We line STEEL PIPE from 4½" O.D. to 30" O.D., and coat-and-wrap STEEL PIPE from ¾" Nom. to 30" O.D. Eminent engineers maintain that STEEL PIPE, when Lined inside and Coated-and-Wrapped outside by the HILL-HUBBELL "factory process," is far more practicable than any other type of pipe.

For ECONOMY and SAFETY—USE STEEL PIPE.



Lining STEEL PIPE

BITURINE AKWALINE Lining in any ferrous pipe prevents tuberculation, corrosion, incrustation, and silting—all of which reduce the original carrying capacity of the pipe. An article on "The Prevention of Corrosion of Pipe" (The American Water Works Association, Volume 16, No. 2, 1936) illustrates the practicability of coal tar lining. Two sections of 6-inch pipe were taken from the Brooklyn System in 1925. One section, laid in 1857, had only one-fifth its original carrying capacity. The other section, laid in 1863, with a coal tar lining, still had, after 62 years of service, its ORIGINAL CARRYING CAPACITY.

In the Hill-Hubbell method, the coal tar enamels are applied, mechanically, in a true multiple coat process. Centrifugal force of the revolving pipe evenly disperses the flow of molten enamel from a slowly withdrawn feed line. The result is a lining of guaranteed minimum thickness and of maximum uniformity. The surface of the lining is as smooth as glass and increases the pipe carrying capacity from 7 to 15% and thereby reduces FOREVER, pumping and operating costs.

Our entire lining application is done AT THE PIPE MILLS, INDOORS. No weather hazards affect the quality of our work. With the most highly developed equipment in the industry to properly handle the coating materials, a Hill-Hubbell job of coal tar enamel lining can not be excelled.

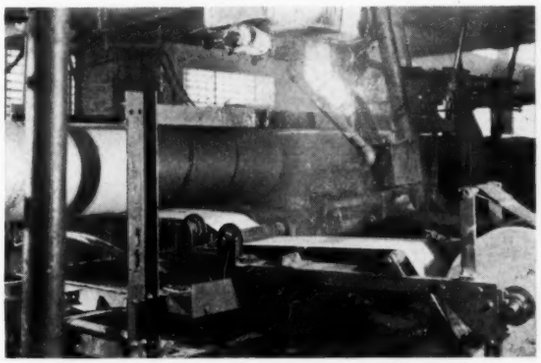
More than 10,000 miles of Steel Pipe have been protected against exterior corrosion by the Hill-Hubbell "factory process," establishing the unquestioned leadership and acceptance of our method. All our work is done, right in the steel pipe mills, mechanically, indoors—away from all weather hazards.

Proper handling of the coating materials is assured, for we use heating kettles of our own design equipped with positive thermostatic control and tireless mechanical agitation.

Because all bituminous coatings are plastic solids, they need the physical strength given them by shielding reinforcing wrappers. Our method always provides this extra protection, positively bonded to the coating—as it should be.

Because we take pride in our craftsmanship, the final shipping-and handling wrapper of heavy kraft paper is imprinted with our name You see our name only on jobs of our Genuine Hill-Hubbell Pipe Protection.

Mill Coating-and-Wrapping is the modern, proven method of pipe protection.



Coating-and-Wrapping STEEL PIPE

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BITURINE Enamel is used for coating STEEL PIPE outside. It is an all-coal tar pitch enamel and has been doing an efficient protection job for over 30 years. BITURINE Enamel, with the additional reinforcement of shielding wrapper, PROPERLY applied at Mills, is now protecting thousands of miles of STEEL PIPE in all parts of the country.

FLOW IN PIPE GRID SYSTEMS

By RICHARD G. TYLER

University of Washington, Seattle, Washington

Hardy Cross's method of solving problems of flow of water in pipe systems has greatly simplified their solution and has supplied the means of checking up existing data on pipe flow now used in water works design. Data on the pressure drop produced in symmetrical pipe grid systems by fire drafts of varying amounts from one or more centrally located fire hydrants may be taken as a case in point. A graph giving head losses for grids of various pipe diameters appeared in the 1925 American Water Works Association Manual "Water Works Practice," p. 308, and is typical of the design data in present use. The writer undertook to check this graph by the application of the Hardy Cross method to the same grid system. Fig. 1 shows the pipe layout for 1, 2 and 4 fire hydrants. It is assumed that the inflow rate at distances of five-500-ft. blocks in any direction from the point of discharge is equal in all pipe lines as shown. For flow from a single hydrant, one-quarter of the discharge comes from each quadrant, so only the pipe system in the quadrant *aoa* need be considered. For flow from the two hydrants *O* and *P* the pipe system to the left of *bxb* is tributary to *O*. For four hydrants, *O* receives water from the quadrant *cxc*. Table I gives the corrected discharge of each pipe for balanced flow from 1, 2 and 4 hydrants. In applying the Hardy Cross method for balancing these flows, four trials gave sufficient accuracy for all practical purposes, while only three were required for draft from our hydrants. The computations using the Hazen-Williams formula are onerous but graphs on log-log paper for

$$h = rQ^{1.85} \text{ and } R = 1.85rQ^{0.85}$$

greatly reduce the time and work required. Since all pipes are of equal diameter and length, r may be taken as *one*. Head losses and flow distribution for any draft can be found by multiplying the unit values given in Table I by the appropriate factor as hereinafter explained. The detailed computations are not shown since the following published papers have described them in detail.

"Analysis of Flow in Networks of Conduits or Conductors," Hardy Cross, Bul. 286, Univ. of Ill., Eng. Exp. Station, 1936.

"Simplified Analysis of Flow in Water Distribution Systems" —J. J. Doland; Eng. News-Record, Vol. 117, p. 475.

"Analyzing Flow in Pipe Networks"—Gordon M. Fair. Eng. News-Record, Vol. 120, p. 342.

In applying successive corrections to these grid systems, it was noted that a correction applied to one small circuit affected adjacent circuits, sometimes changing the algebraic sign of the correction to be made. Different combinations of flow may give approximately equal head losses and an additional correction by the Hardy Cross method will give somewhat different flows without an appreciable change in the total head loss.

Computing Pressure Drop Simplified

An accompanying graph (Fig. 2) gives the pressure drop in the selected pipe system for a wide range of drafts. This graph is constructed for pipes of from six to twelve inches in diameter, 500 ft. on centers both ways, and with flow from one, two and four fire hydrants. The computations for the various pipe sizes and discharges are easily made by substituting the desired discharge for the unit figures shown in Table 1. For example, in determining the pressure drop for a fire flow of 2000 gpm from

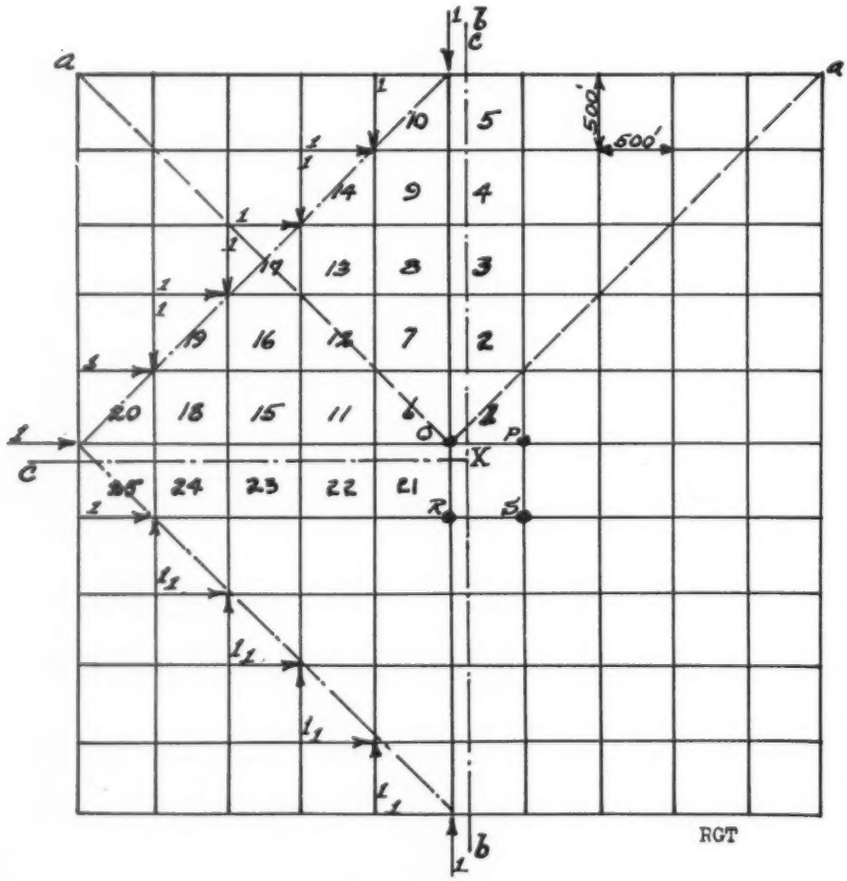

Fig. 1.—Grid Systems
(Showing location of fire hydrants and assumed unit inflow at points 2500 ft. distant from hydrants).

TABLE I—Flow in Pipes of Symmetrical Grid Systems for Inflow Shown in Fig. 1 (Adjusted)

Line	Number of Fire Hydrants in Service		
	1	2	4
1- 6	9.00	6.25	5.00
2- 7	3.44	3.23	2.89
3- 8	2.34	2.06	1.95
4- 9	1.70	1.49	1.51
5-10	1.00	1.00	1.00
21- 6	9.00	6.50	5.00
6- 7	2.78	3.02	2.11
7- 8	0.55	1.17	0.94
8- 9	0.32	0.57	0.44
9-10	0.35	0.49	0.51
6-11	2.78	1.65	2.11
7-12	2.78	2.16	2.11
8-13	1.89	1.71	1.77
9-14	1.65	1.51	1.49
22-11	3.44	3.20	2.89
11-12	2.78	2.51	2.11
12-13	1.44	1.62	1.28
13-14	0.56	0.77	0.72
11-15	0.55	0.53	0.94
12-16	1.44	1.13	1.28
13-17	0.32	1.23	1.28
23-15	1.44	2.14	1.95
15-16	2.34	1.91	1.77
16-17	1.89	1.52	1.28
15-18	1.44	0.25	0.44
16-19	0.56	0.48	0.72
24-18	1.70	1.64	1.51
18-19	1.65	1.68	1.49
18-20	0.35	0.32	0.51
25-20	1.00	1.00	1.00

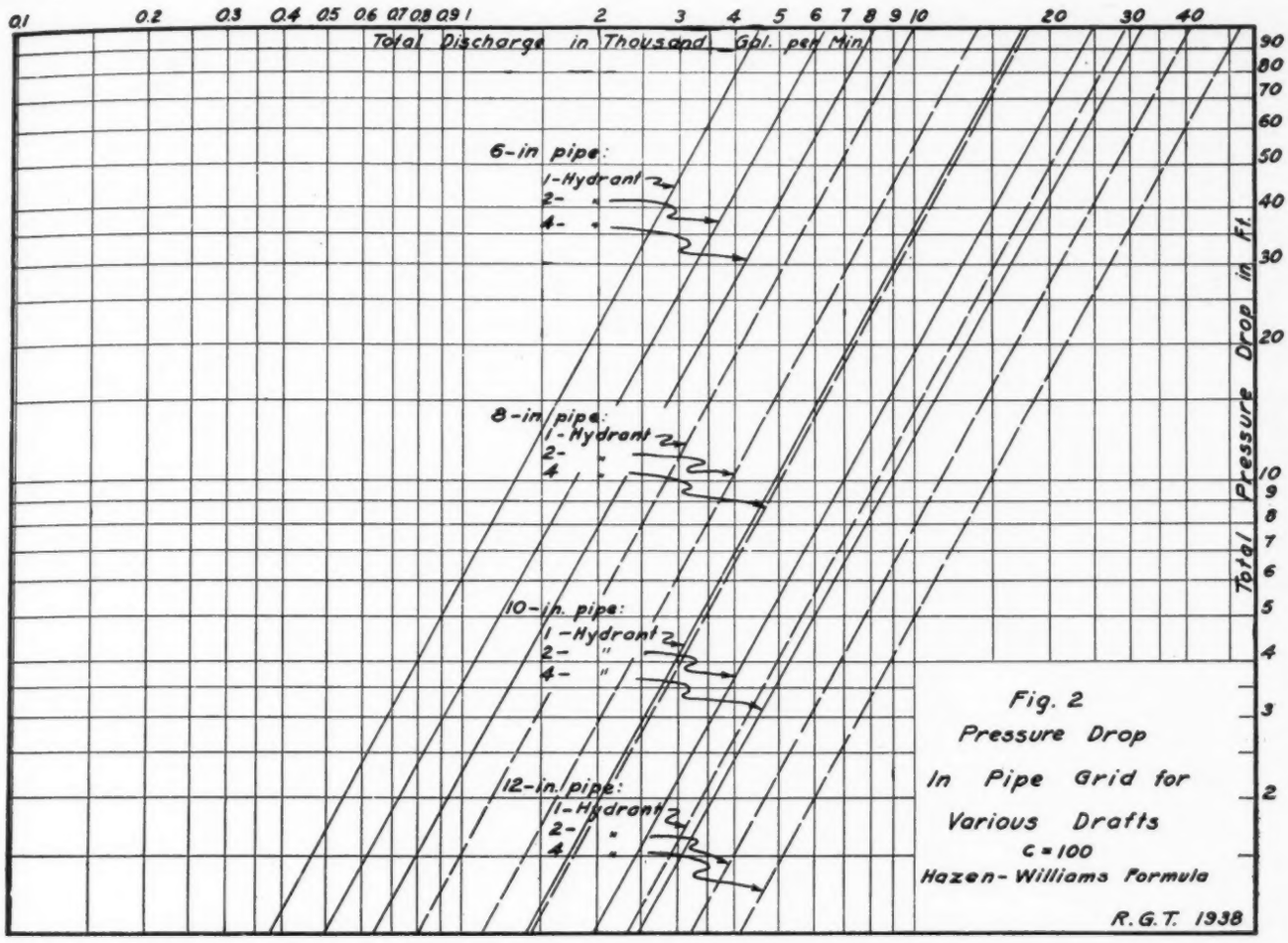

Fig. 2.—Pressure Drop in Pipe Grid for Various Draughts
(By Hazen-Williams Formula, assuming $C = 100$)

a single fire hydrant on an 8-inch grid system, one would proceed as follows:

Since one-fourth of the total flow, or 500 gpm, approaches the hydrant from each quadrant, this 500 gallons in equivalent to the 9.0 units in Table 1. In the next block 3.54 nits would therefore equal 197 gpm, while the flow in the next three sections of this pipe as we go further from the hydrant is 122, 91, and 56 gpm, respectively. Head losses for each of these flows through 500 feet of 8" pipe are taken from some of the graphs in current use, giving a total head loss of 5.32 ft. in the straight 2500 ft. of pipe leading to the hydrant. Similarly, if it is desired to check this head loss by that along some other path as, for example, the zigzag line following most closely the diagonal which separates the quadrants, the latter's loss is found to be 5.24, which checks the above figure quite closely. In similar fashion, the losses were determined for other desired flows for the various pipe diameters and number of hydrants shown, and the results have been reproduced in Fig. 2, giving the data in a form for convenient use. These computations are facilitated by constructing a graph on log-log paper, giving the relationship between Q and h per thousand ft. for the pipe sizes used.

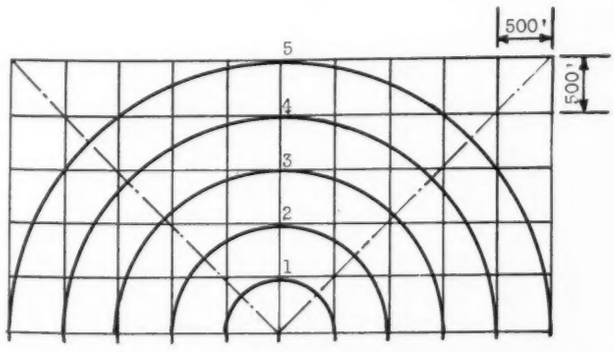

Fig. 3.—The Circle Method of Computation
(Showing pipes cut in a single quadrant.)

After having determined the position on the graph for a given pipe size, lines representing flow conditions for pipes of other diameters with the same number of hydrants will be parallel thereto on log-log paper and the spacing between them and the computed line will be in inverse proportion to the fifth powers of the respective diameters, regardless of whether the Chezy or the Hazen-Williams formulas are used. Thus, if the 8" pipe losses are taken as a basis, head losses in a similar 6" system may be obtained by multiplying values by $\frac{8^5}{6^5}$, or 4.21. The curves in Fig. 2, however, were constructed by computing several points on each curve from the data in Table 1. Curves based on the formula $h = f \frac{l}{d} \frac{v^2}{2g}$ check these curves almost exactly and make the computations much simpler since $n = 2$ instead of *1.85*.

The Circle Method

It is of interest, also, to check the accuracy of another of the earlier methods which has been frequently used by designers of water works systems. This is the *circle method* which has the advantage of simplicity of computations. It is too well known to require a detailed description. Fig. 3 illustrates its application to the present grid system with flow from a single fire hydrant. In

this figure, to simplify the computations, the radii are taken so that the curves cut just inside of the pipe intersections. For example, Curve 1 cuts a single 8" pipe within the quadrant shown so that for 4000 gpm discharge from the hydrant, this 500-ft. length of pipe carries 1000 gpm with a head loss of 13.5 ft. Curve 2 cuts three pipes, and since the total length of pipe between Circle 1 and Circle 2 equals 2200 ft., this would give an average length of 733 ft. for the three pipes cut, each carrying one-third of the 1000 gallons with a head loss of 2.6 ft. The other computations are shown in Table II, and it is apparent that the total pressure drop, as determined by the circle method, is 18.2 ft., while the corresponding value taken from Fig. 2 is 19.0 ft. Computations for other discharges gives results that check within a similar range of accuracy.

Comparing Tables I and II and Fig. 2, the errors introduced in assuming equal flow through the various pipes between adjacent circles is apparent. These errors, plus and minus, are averaged by totaling the pipe lengths between circles and dividing this total and the total flow by the number of pipes cut. The errors balance to some extent so that the final results obtained by the circle method check approximately the data from the curves in Fig. 2.

For regular grid systems such as those dealt with in this discussion, it is far simpler to use the circle method in preference to the Hardy Cross method. And, when its accuracy is sufficient for the problemas under consideration its use is justified, but where greater accuracy is required the Hardy Cross method should be used.

The larger part of the pressure drop naturally occurs in the section of pipe nearest the fire hydrant because of the relatively greater discharge in this pipe. In fact, for flow at a single hydrant an average of 75.0% of the total pressure drop occurs in this section of the pipe for all diameters and for 500 ft. pipe spacing. Fig. 4 givesthe head losses at varying distances from the point of draft and for discharges from 1, 2 and 4 hydrants.

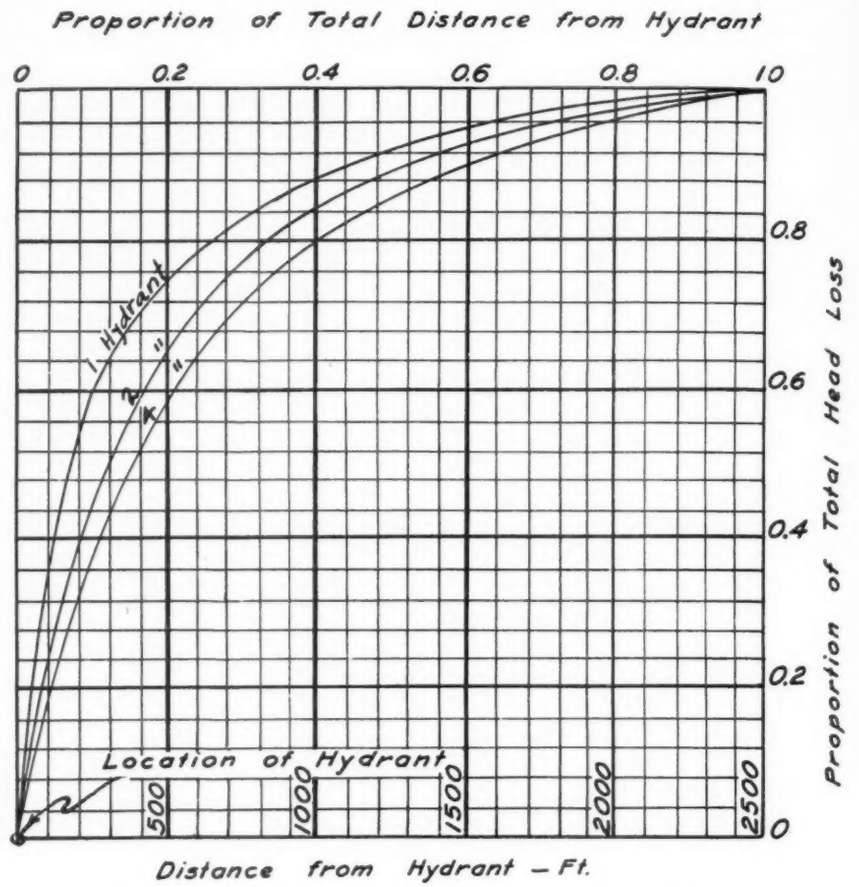

Fig. 4.—Relation of Pressure Losses to Distances from Hydrants

TABLE II—Computations Illustrating Use of Circle Method of Determining Head Losses in Pipe Systems

Circle	Total Length Ft.	No. Pipes Cut	Length Per Pipe Ft.	Diam. In.	Discharge Per Pipe gpm.	Head Loss Per 1000 Ft.	Total Head Loss Ft.
1	500	1	500	8	1000	27	13.5
2	2200	3	733	8	333	3.6	2.6
3	3900	5	740	8	200	1.5	1.1
4	5400	7	771	8	143	0.83	.6
5	7000	9	778	8	111	0.5	.4
					Total Pressure Drop		= 18.2
					Value from Fig. 2		= 19.0

Obtaining a Close Approximation

Obviously, a close approximation of the head loss in any regular grid system could be obtained with a minimum of effort by equating the head loss in this first section of pipe to the proper factor from Fig. 4. In the above case, for example, if the head loss in 500 ft. of 8" pipe carrying 1000 gpm is 14.2 ft., then a grid of 8" pipe on 500 ft. centers would deliver 4000 gpm through a single hydrant with a pressure drop of $\frac{14.2}{0.75} = 19.0$ ft. Since the accuracy obtained would equal that of the basic assumptions used in more detailed methods of computation, it would be advantageous to use Fig. 4 for pipe sizes or lengths not included in Fig. 2 instead of the Hardy Cross method. Since pipe losses vary directly with pipe lengths, Fig. 4 can be used also for grids with any spacing so long as the pipes are equidistant in both directions. For example, the head losses to be expected in a 10" grid, with pipes 300 ft. on centers, would be 3/5 of the values given in Fig. 2. Or with flow from a single hydrant, from Fig. 4, the total loss in the grid would be 4/3 of the loss in 300 ft. of 10" pipe whose discharge was one-fourth of the total fire draft.

Fig. 4 also shows how rapidly the head loss with flow from one, two and four hydrants decreases as the distance from the hydrant increases. In all computations, it has been assumed that the head losses beyond a point 2500 feet (or five city blocks) distant from the hydrant are so small as to be negligible. The error introduced by this assumption can be easily determined from Fig. 4 for any given case. For example, the loss in a distance of 2500 ft. is 98.5% of that in 3125 ft., even though the 2500 ft. is only 80% of the total distance.

The data given in Figs. 2 and 4 check with reasonable closeness the curves in the A. W. W. A. Manual mentioned above, indicating that this earlier work was accurate even though less satisfactory methods of computation were then available than at present.

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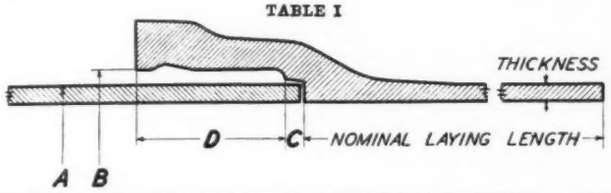
Super-deLavaud Pipe with bell and spigot joints is available in all sizes from 3″ to 24″ and in 12-foot and 18-foot lengths. The joint is particularly adaptable for lead, cement, joint compound or rubber ring assembly. The centering ring insures easy alignment and uniform distribution of the jointing material. The process by which this pipe is produced assures concentricity, evenness of metal and freedom from sand or slag inclusions. The bell and spigot joint, made with lead or other jointing materials, shows ample strength to resist pulling apart. If required to meet service conditions, pipe will be furnished with special linings. All Super-deLavaud Pipe with bell and spigot joints are made to meet Federal Specification WW-P-421. Write for descriptive booklet.

TABLE I



Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
3	150	.33	140	11.8		
3	250	.36	155	12.8		
4	150	.34	195	16.4	285	15.9
4	250	.38	220	18.4	325	17.9
6	150	.37	315	26.3	460	25.5
6	250	.43	350	29.3	515	28.5
8	150	.42	475	39.4	690	38.3
8	200	.46	510	42.4	745	41.3
8	250	.50	545	45.5	800	44.3
10	150	.47	640	53.3	935	51.8
10	200	.52	700	58.3	1025	56.8
10	250	.57	760	63.3	1115	61.9
12	150	.50	810	67.4	1180	65.6
12	200	.57	905	75.4	1325	73.7
12	250	.62	990	82.5	1450	80.7

Nominal Diameter Inches	Class or Maximum Working Pressure	Average Thickness	Nominal Laying Length			
			12-Foot Length		18-Foot Length	
			Weight of Pipe Pounds	Weight Per Foot Including Bell	Weight of Pipe Pounds	Weight Per Foot Including Bell
14	100	.48	920	76.5	1340	74.3
14	150	.55	1060	88.5	1555	86.3
14	200	.62	1190	99.0	1735	96.3
14	250	.69	1320	110.0	1930	107.3
16	100	.52	1130	94.2	1645	91.4
16	150	.60	1320	110.2	1935	107.4
16	200	.68	1490	124.1	2175	120.7
16	250	.75	1635	136.1	2390	132.7
18	100	.56	1365	113.8	1990	110.6
18	150	.65	1595	132.8	2330	129.6
18	200	.74	1810	150.9	2645	146.9
18	250	.83	2015	168.0	2950	163.9
20	100	.58	1585	132.0	2305	128.0
20	150	.68	1860	155.0	2720	151.0
20	200	.78	2125	177.1	3105	172.4
20	250	.88	2365	197.1	3465	192.4
24	100	.64	2085	173.8	3035	168.6
24	150	.76	2480	206.8	3630	201.6
24	200	.88	2855	237.8	4170	231.6
24	250	1.00	3200	266.8	4690	260.6

Threaded Cast Iron Pipe Centrifugally Cast

Super-deLavaud Cast Iron Pipe is now being manufactured in "iron pipe sizes" with threaded joints to meet the demand for a better and more durable pipe. There are two distinct types of service for which Super-deLavaud Cast Iron Pipe may be used: pressure service for water, gas, steam or similar liquids and gases; and drainage service. Pressure pipe is made to meet the requirements of Federal Specifications WW-P-421 and is supplied in three classes: standard, extra-strong and double-extra-strong. Drainage pipe, used for waste, vent and drain work, is a lighter pipe for use in buildings and elsewhere where a tight screw-coupled joint is needed. Drainage pipe is made to meet the requirements of Federal Specifications WW-P-356.

THREADED CAST IRON PRESSURE PIPE

(Made to meet the requirements of Federal Specifications WW-P-421)

Size Inches	Class	Nominal Length, Feet	Outside Diameter, Inches	Nominal Thickness, Inches	Threads per Inch	Weight per Foot Pounds
3	Standard	12	3.50	.36	8	11.08
	X-strong	12	3.50	.45	8	13.45
	XX-strong	12	3.50	.48	8	14.21
4	Standard	18	4.50	.38	8	15.34
	X-strong	18	4.50	.48	8	18.91
	XX-strong	18	4.50	.52	8	20.29
5	Standard	18	5.56	.40	8	20.22
	X-strong	18	5.56	.49	8	24.40
	XX-strong	18	5.56	.53	8	26.15
6	Standard	18	6.63	.43	8	26.13
	X-strong	18	6.63	.51	8	30.59
	XX-strong	18	6.63	.55	8	32.78
8	Standard	18	8.63	.50	8	39.85
	X-strong	18	8.63	.56	8	44.29
	XX-strong	18	8.63	.60	8	47.22

THREADED CAST IRON DRAIN PIPE

For Waste, Vent and Drainage Service

(Made to meet the requirements of Federal Specifications WW-P-356)

Size Inches	Nominal Length Feet	Outside Diameter Inches	Minimum Thickness Inches	Threads per Inch	Weight per Foot Pounds
3	12	3.50	.26	8	9.41
4	18	4.50	.29	8	13.75
5	18	5.56	.33	8	19.05
6	18	6.62	.38	8	26.22
8	18	8.62	.44	8	39.82

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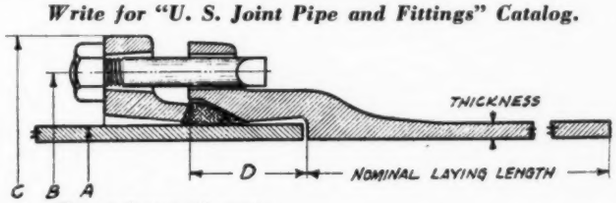

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HYDRANT DISCHARGE MEASUREMENTS

Practical Methods of Making Measurements; Computing and Applying Results

By P. S. WILSON

Water Works Consultant, Glen Ridge, N. J.

The measurement of the discharge or flow from fire hydrants is a common procedure for engineers engaged in testing the fire fighting capacity of a water system. The fact is frequently overlooked that such measurements may also be very usefully applied to many other vital problems with which the operator of a water supply system is regularly confronted. It is likewise not always realized that this work may be performed with but a small expense for equipment and without the need for special technical training.

Actual measurements of the flows taking place in a water distribution system may furnish extremely valuable information to the water works operators. A water distribution system is different from most of the equipment with which other business is conducted. It is buried underground and is not subject to ready inspection. The greater portion of it has not been seen for a generation or more. Its present operator has never seen most of it and almost all he knows of it is what he has been told second or third hand or what he learns from maps and records which are in many cases woefully deficient. What information he does obtain about his system is mostly history,—what it was when it was last seen, years before, not what it is now. It is on account of these conditions that actual tests and measurements are of such great value. One can authorize for a long time as to whether a certain valve is open or shut and one may even operate the valve one way or another and still not know much more than before. But if the water in proper quantity flows through that valve and evidences itself on the other side, then the question is settled and there is no more possibility for argument.

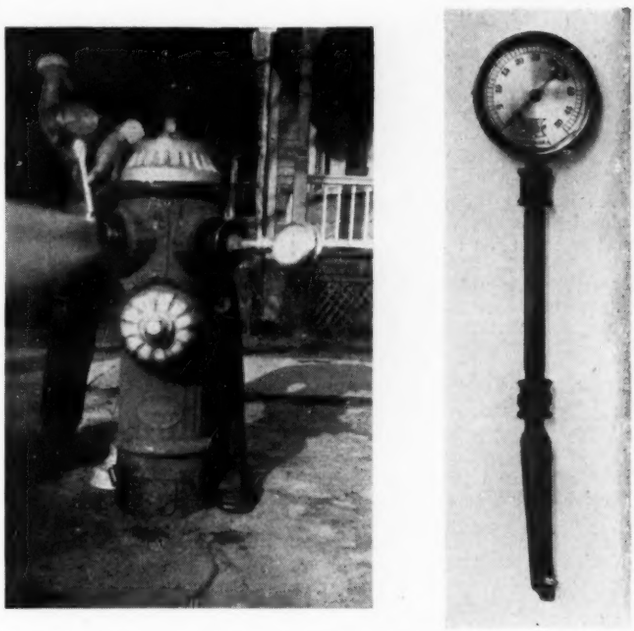
There are two principal methods of making field measurements of the flows in water distribution systems. One of these is by means of the Pitot orifice tube inserted through a corporation cock in the side of a main. Such measurements when properly applied are of inestimable value. However, a method, of making tests, which is more readily available to the average operator, involves the measurement of hydrant discharges and less time, expense, and equipment are necessary therefore. Measurements so made are not, of course, a complete substitute for Pitot measurements in the pipes, but in many cases they may suffice in themselves to answer the questions at hand. Even if they do not, they always form a valuable guide and adjunct in the making of further and more elaborate tests, if these are later found necessary.

Methods of Measuring Hydrant Discharge

Measurements of the discharge from an ordinary fire hydrant with sufficient accuracy for most practical purposes is not difficult. By the exercise of care and good judgment, results may be obtained within fairly close limits of accuracy. Rough and ready methods are for the most part amply sufficient, since, for the purposes usually involved, the conclusions arrived at would not be changed by a variation of five or ten per cent one way or the other in the test results. Some of the rather approximate methods to be given must be judged with this fact in mind.

The discharge from a hydrant nozzle is determined from the size or cross sectional area of the emerging stream and from the average velocity of that stream. From these two figures the discharge may readily be computed or may be directly read from tables or diagrams such as those appended to this article.

Measuring Nozzle Diameter—Observation of flow from hydrant nozzles shows that it completely fills the nozzle, as a general rule. Therefore, a simple measurement of the internal diameter of the hydrant nozzle serves to make known the diameter of the stream of water. The entrance to the nozzle from within the barrel may occasionally (particularly in some old styles of hydrants, and hydrants with independently gated nozzles) be sharp enough to cause the emerging stream to be contracted slightly below the size of the nozzle and if such an effect is noted it should be allowed for in the diameter used. The internal diameter of each nozzle used should be carefully measured to the nearest one-sixteenth of an inch. An ordinary carpenter's rule is satisfactory for this purpose.



Two Methods of Determining Velocity of Nozzle Discharge. (Gage on Pitot Tube Held in Stream and Gage, Indicating Barrel Pressure, Show Practically Same Readings)
Hydrant Pitot Tube with Gage at Right

Determining Stream Velocity—The average velocity of the emerging stream of water may be determined in either of two ways. The most common method is by the use of a hydrant Pitot tube which may be inserted into the stream and which transforms the velocity head of the stream into the equivalent pressure head and registers it on an attached pressure gage. This instrument is here pictured. It consists of a hollow blade or "cut-water," shaped so that it may be thrust into the stream without unduly deflecting it. At the end of the blade is a small opening which points directly against the flowing water. The force of the stream striking into this opening creates a pressure in it which is transmitted through the hollow blade and handle to the pressure gage. The gage is an ordinary good pressure gage, except that it should be graduated to read more closely than most gages. The gage most frequently used is graduated every pound and only reads up to about fifty pounds per square inch pressure. It must be a good grade of gage to maintain its accuracy with such close reading. For some purposes it is of value to have a very low pressure gage graduated to half pounds. Sometimes the Pitot tube and the gage are held in place in the stream by a device which clamps over the outside of the nozzle. This device is not ordinarily considered necessary, however, and its use results in greater damage to the Pitot tube if struck by a stone or other object carried by the water. The edges of the blade and the small orifice into it must be kept sharp and symmetrically shaped or the accuracy of the instrument will be seriously affected.

In use, the Pitot tube is held in the stream and the pressure read while the small orifice is held at the center of the stream and pointing directly against the flow. Occasionally on large nozzles it is advisable to take a rough average of the pressures across the stream at different points horizontally and vertically. In most cases the pressure at the center will be found to be practically the average. In no case should the pressure very near the edge (within about one-fourth inch) be considered.

The other method of determining the velocity of the stream, and one which has been occasionally found more convenient by the writer, consists merely in placing on one of the hydrant nozzles a cap having an ordinary pressure gage tapped into it then allow the discharge to take place through the other nozzles. Due to the free discharge from the nozzles, practically all of the pressure head remaining in the barrel during the flow is transformed into velocity head in the jets. Since that is practically the only source of velocity head in the jets, the ordinary pressure gage indicating the pressure in the barrel will read substantially the same as a gage on a Pitot tube held in a jet. This fact may be readily confirmed by trial. In this way the discharge of a hydrant may be measured with fair accuracy, without the Pitot tube, merely by the use of a pressure gage, the gage reading being used to compute the discharge in the same manner as if it were a Pitot tube reading. The same type of gage should be used for this method as described above for the Pitot tube. Any pressure gage may be used, however, the accuracy of the results depending upon the accuracy of the gage and the closeness of the graduations and readings.

An accompanying illustration shows a Pitot tube with gage being held in the stream from one hydrant nozzle while a pressure gage on the other nozzle is at the same time indicating the pressure in the barrel. This illustrates the two methods of determining the velocity head of the stream. Unfortunately the photograph does not make it possible to see what the gages are reading; actually they show the same—18 pounds per square inch. In using the Pitot at low velocities, where a quarter pound makes an appreciable difference, the instrument should be held horizontally so that the pressure gage will be at the same elevation as the nozzle.

With the same accuracy of gage reading the only inaccuracies in the second method as compared with the use of the Pitot tube are in the fact that there is a slight loss of head in entering and flowing through the nozzle and in the assumption that the velocity head in the barrel at the point of pressure reading is zero. This latter assumption is justified because the velocity in the barrel is low compared to that in the jet and the pressure reading is taken opposite or above the other nozzles which are discharging. In any case, as before mentioned, trial will show that the results are in general substantially the same for both methods. If the hydrant Pitot tube is at hand, its use is best and most convenient; the availability of the other method, however, should always be borne in mind.

The pressure gage on one nozzle, of course, prevents the use of that nozzle for the discharge of water. This is not always a disadvantage, however, particularly when the hydrant is equipped with a steamer nozzle which may be used for attaching the gage.

A fact which may readily be perceived from the foregoing is that, when measuring the velocity with a Pitot tube, readings need only be taken (except as a check) in one of several nozzles discharging simultaneously because readings in all of the nozzle streams should be practically alike.

Computation of the Flow

By the measurement of the nozzle diameter we now have obtained the diameter of the stream of water, and from the pressure gage reading we have obtained a figure which bears a known relation to the velocity of the stream. The formula for the discharge may now be readily derived from the fact that:

Discharge = (area of stream) × (average velocity)

If d = the internal diameter of the hydrant nozzle in inches, then, using the formula for the area of a circle, the area of the stream is $\frac{3.14 \times d^2}{4}$ square inches. For convenience in computing, this is divided by 144—the resulting formula being $0.00545 \times d^2$ to obtain the area of the stream in square feet.

The pressure gage reading, in pounds per square inch (p) is changed to feet of water head by multiplying it by 2.31. A fundamental hydraulic formula states that the velocity of the stream of water is equal to the square root of the pressure head multiplied by the square root of two times the acceleration of a falling body, due to gravity. This latter (g) is a constant and is equal to 32.2 in foot and second units. Therefore:

(a) Velocity of the stream in feet per second =
$$\sqrt{2.31 \times p} \times \sqrt{2 \times 32.2} = 12.2 \times \sqrt{p}$$

(b) Discharge in cubic feet per second =
$$0.00545 \times d^2 \times 12.2 \times \sqrt{p} = 0.0665 \times d^2 \times \sqrt{p}$$

(c) Discharge in gallons per minute =
$$29.9 \times d^2 \times \sqrt{p}$$

The velocity of the stream of water as determined by either of the two methods described does not take into account the very low velocity of the stream around the edges where it is held back by its contact (friction) with the nozzle. To make allowance for this, as well as to allow for a possible slight contraction of the jet, it is necessary to make use of a coefficient in computing the results. This coefficient has been determined experimentally by checking hydrant flow measurements against other and more accurate means of metering the flow. The coefficient should, theoretically, be different for different hydrants, but it is sufficiently accurate for the purposes and means of measurement under discussion to use an average figure which has been found by experiment to be about correct for most cases. The figure most generally used is 0.90 and thus the formula derived above is modified as follows:

(d) Discharge in gallons per minute =
$$0.90 \times 29.9 \times d^2 \times \sqrt{p} = 26.9 \times d^2 \times \sqrt{p}$$

For convenience the 26.9 may be rounded off to an even 27 without introducing an error of importance, resulting in the completed formula:

(e) Discharge in gallons per minute =
$$27 \times d^2 \times \sqrt{p}$$

in which d = diameter of nozzle in inches and, p = gage reading in lbs. per sq. inch.

The Advantage of Tables and Charts

From this formula tables may be constructed in which the discharge is given for each combination of diameter of nozzle and Pitot pressure head and from which the result of the measurement may therefore be read directly without computation. A specimen is shown in Table 1. The discharges in this table are given to the nearest ten gallons per minute. Tables may be made up very conveniently to fit in field note books. For special purposes they may be abbreviated or enlarged either in range or in closeness of reading.

Another method of handling the formula is by the use of diagrams. A particularly convenient form for such a diagram, which the author has never seen in use elsewhere, accompanies this article. In this diagram measurements horizontally from the origin or zero are proportional to the square root of the Pitot pressure head, $\sqrt{p}$. Measurements vertically are proportional to the discharge of the hydrant nozzle in gallons per minute. An inclined straight line passing through the origin then represents each value of the nozzle diameter, (d). A heavy line is drawn for each size of nozzle in use using the theoretically correct value of d,—for example 2½ inches for an ordinary hose nozzle. Light lines are then drawn on the diagram below and above the first ones representing ⅛-inch undersize and oversize of each nozzle. From these three lines values for each 1/16 to ¼-inch under and over the nominal sizes may readily be read on the

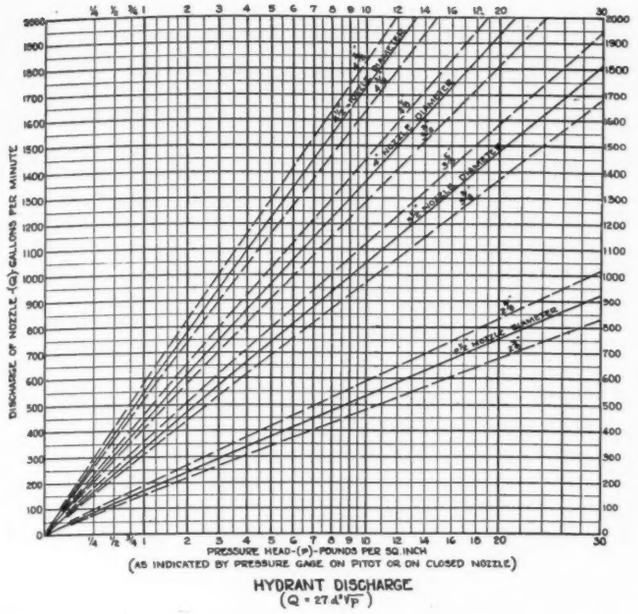
TABLE 1—HYDRANT DISCHARGE*

Gallons per minute = $27 d^2 \sqrt{p}$

Gage Reading—Hoze nozzle diameter in inches [d]

p	2 7/8	2 3/4	2 5/8	2½	2 3/8	2¼
¼	70	80	80	80	90	90
½	100	110	110	120	120	130
¾	120	130	140	150	150	160
1	140	150	160	170	180	190
1¼	160	170	180	190	200	210
1½	180	190	200	210	220	230
1¾	190	200	210	220	230	250
2	200	210	230	240	250	260
2½	230	240	250	270	280	290
3	250	260	280	290	310	320
3½	270	280	300	320	330	350
4	290	300	320	340	350	370
4½	310	320	340	360	380	390
5	320	340	360	380	400	420
5½	340	360	380	400	420	440
6	350	370	390	410	430	460
6½	370	390	410	430	450	470
7	380	400	420	450	470	490
7½	400	420	440	460	490	510
8	410	430	450	480	500	530
8½	420	440	470	490	520	540
9	430	460	480	510	530	560
9½	440	470	490	520	550	570
10	460	480	510	530	560	590
11	480	510	530	560	590	620
12	500	530	560	590	610	650
13	520	550	580	610	640	670
14	540	570	600	630	660	700
15	560	590	620	650	690	720
16	580	610	640	670	710	740
17	600	630	660	700	730	770
18	610	650	680	720	750	790
19	630	660	700	700	770	810
20	640	680	720	750	790	830
22	680	710	750	790	830	870
24	710	750	790	830	870	910
26	740	780	820	860	900	950
28	760	810	850	890	940	980
30	790	830	880	920	970	1020

*Discharges shown to nearest 10 gals. per min.


DISCHARGE OF NOZZLE-(Q)-GALLONS PER MINUTE
PRESSURE HEAD-(P)-POUNDS PER SQ INCH
(AS INDICATED BY PRESSURE GAGE ON PITOT OR ON CLOSED NOZZLE)
HYDRANT DISCHARGE
(Q = 27.4 d² √P)

Hydrant Discharge Diagram. (Courtesy, Community Water Service Co.; this Chart Having Been Prepared by the Author While Connected with the Company)

diagram. This covers the usual variation of the nozzles. It is to be noted that the horizontal distances on the diagram are not directly proportional to the pressures but to the square roots of the pressures. This results in uneven spacing of the figures, but by so constructing the diagram the lines representing the nozzle diameters may be drawn straight, whereas otherwise they would be curved. The uneven spacing of the pressure lines makes accurate interpolation difficult, and therefore enough lines are drawn on the diagram to make this unnecessary. Having made a discharge measurement this diagram is used as follows: Pick the vertical line representing the Pitot pressure reading, follow it up or down to where it crosses the line representing the actual measured internal diameter of the nozzle, estimating where that line would be if the correct one is not on the diagram. Then follow the horizontal lines to right or left and read the discharge on the vertical scale.

A Few Comments

A careful study of the formula and the tables and diagrams leads to a number of important observations on the carrying on of this work. When the Pitot pressure reading is low, a slight difference in the reading will result in a very large percentage difference in the result, whereas at higher pressures a half pound or even a pound does not make much difference. For instance the difference between 1 and 2 pounds per square inch makes about 40 per cent difference in the discharge while the difference between 10 and 11 pounds per square inch makes only about 5 per cent difference. This fact is the reason for making the pressure differences in the table and diagram smaller in the lower range. It also indicates the necessity for making very careful Pitot pressure determinations in the field, particularly at low pressures. Gages should be closely graduated as before mentioned and should have at least three inch dials. On particular work they should be calibrated with a dead weight tester before and after using and corrections applied to the readings if necessary. Gages should be handled gently and with care so as to maintain their accuracy. Since they will probably not read as high as the static pressure in the mains, care should be taken when taking pressures on a closed nozzle not to subject them to too much pressure. Other gages must, of course, be provided for taking the direct main pressures.

Emphasis must be placed on the necessity for keeping the connections between the Pitot blade and the pressure gage absolutely tight. A very slight leak, in fact only a drip which in the general splashing may not be noticed, is sufficient to make the reading considerably in error. The connections should be made up tightly with wrenches and should not be loosened in order to turn the gage into a more convenient position.

It will be noted that a 1/16-inch difference in the diameter of the nozzle makes a much greater percentage difference at high discharges than at low ones. This is the opposite from the effect of the pressures. In spite of this it will usually result in greater accuracy to use as few and as small nozzles as possible in a measurement. The use of steamer nozzles is advised only on work where approximate results would be satisfactory. Further experiments may show that a slightly different coefficient should be used in computing the discharge of the larger sizes of nozzles.

Fire Flow Tests

The making of fire flow tests is the most obvious use to which hydrant flow measurements may be put. Such tests consist in the determination of what amount of water is available at a given hydrant, or at a given group of hydrants, for use by the fire department. This test is the one usually made by the engineers of the National Board of Fire Underwriters in rating a system for fire protection. So much has been written on such tests that they need be only mentioned here. Simultaneous readings are taken on as many hydrants in a group as are needed in order to develop the capacity of the system. At the same time a record is kept at an adjacent hydrant (not discharging), of the residual pressure. From a set of such readings the discharge capacity of the system at that point with any residual pressure may be known.

The residual pressure mentioned above is the pressure remaining in the mains during the time that a flow test is taking place. This pressure is determined by the readings of a pressure gage attached to a hydrant which is *not* discharging but which is located close by and, if possible, on the side opposite to the direction from which the flow is coming. The actual capacity of the distribution system at a given point is usually considered to be the discharge with the residual pressure drawn down to some stated figure. By this method the results of flow tests at different points and on different systems are made comparable. When fire engine pumpers are to be used then the maximum capacity of the system may be considered as the discharge with the residual pressure drawn down to 20 lbs. per sq. in. If reliance is placed on direct hydrant pressure for the hose streams then the residual pressure can not be drawn down nearly so low and the maximum capacity of the system at such higher residual pressures will be less. Sometimes the capacity of a system is referred to as the discharge with a drop in pressure of 20 lbs. per sq. in., in other words, with a residual pressure 20 lbs. per sq. in. less than the original pressure before the hydrants were opened. This will usually be a very different figure from the capacity at 20 lbs. per sq. in. minimum residual pressure.

It is usually difficult or impossible to make a flow measurement at exactly the rate of discharge which will result in the residual pressure desired. It is customary, therefore, to make the measurement at some rate of discharge as near as convenient to that producing the effect desired and then to compute what the discharge would have been at the residual pressure desired. This may be done by applying the fact that the discharge is approximately proportional to the square root of the drop in pressure.

If, for example, the original pressure in the mains before opening the hydrants had been 56 lbs. per sq. in., and the residual pressure during a flow of 2680 gallons per minute had been 32 lbs. per sq. in., then the drop in pressure during that flow was 24 lbs. per sq. in. Suppose now that it were desired to know in this example what the discharge would have been with a residual pressure of 20 lbs. per sq. in. The drop in pressure in that case would have been 36 lbs. per sq. in. It is then merely necessary to multiply the measured discharge (2680 gal. per min.) by the square root of 36 (which is 6.0) and divide by the square root of 24 (which is 4.9).

$$\frac{2680 \times 6.0}{4.9} = 3280$$ gal. per min. which would have been the discharge at 20 lbs. per sq. in. residual pressure.

If Q_1, is the measured discharge with a drop in pressure of D_1; and, Q_2 is the discharge which would have taken place with a drop in pressure of D_2 then the above method may be stated in a general formula as follows:

$$Q_2 = Q_1 \times \frac{\sqrt{D_2}}{\sqrt{D_1}}$$

This method, as stated before, is only approximate and it should not be considered very reliable if the drop in pressure at the measured discharge is very greatly different from the drop in pressure desired. The method is, however, entirely satisfactory for most practical purposes.

Fire flow tests may indicate not only whether the system has the desired capacity or not, but they may be amplified to give

information as to what work should be done to increase the capacity. For example, by taking a record of the pressures in the system during the flow test at various points progressing back toward the source of supply, it may be conclusively shown whether a restriction is in the principal supply mains or whether it is in the local mains adjacent to the test. By cutting out certain mains during the test still further information may be gained as to the actual conditions existing; closed valves or other obstructions, defective hydrants, or large leaks may be discovered and located. This work opens up a great field for the display of ingenuity on the part of the operator since the exact procedure is subject to unlimited variation and depends upon the arrangement of the particular system under test.

For further details and information regarding fire flow tests the reader is referred to a paper published in the *Journal of the American Water Works Association*, Volume 12, No. 2, October, 1924, by Mr. George W. Booth.

Other Uses for Hydrant Flow Measurements

There are many other varieties of tests, measurements and experiments which may be performed on a distribution system through the use of hydrant discharge measurements. They may be used in making determinations of the friction coefficient in certain mains of the system. By isolating a stretch of pipe so that the feed into it is from one end only, a flow through it may be created which can be measured at its discharge from a hydrant or hydrants at the end of the section under test. If pressures are taken simultaneously during the flow at intermediate hydrants or other connections of known elevation along the main, then, from the data so obtained, the loss of head and the friction coefficients of each section may be computed. Obstructions or closed valves may also be located through the unequal drops in pressure in different sections along the line when such difficulties exist.

Such tests are of value in determining the necessity for or advisability of cleaning a main and likewise, in determining the effectiveness of the cleaning after it has been performed. If they are made periodically after cleaning, valuable data will be obtained as to the speed and degree of the return of roughness in the pipe, thereby indicating the true value of the cleaning and the advisability of recleaning or of cleaning other mains. Also the efficacy of corrosion control procedures will be disclosed and the results of changes evaluated.

In those cases where a company's records are inaccurate, loss of head tests may be quickly made to provide an accurate indication of the size of any main which is in doubt.

When flushing out sediment or other deposits from the pipes of a system it is of great value to make a rough check of the discharge of the hydrants or blow-offs in use in order to be certain that a sufficient velocity has been created in the main or mains supplying that point to properly clean them out. From 4 to 6 feet per second is usually considered the minimum that will effectively flush out a main, so that the material remaining will cause no further difficulty by being stirred up by normal flows.

It is difficult to foresee all of the benefits which may come of making tests such as these on a distribution system. One of the greatest benefits is that, no matter what their nature, they will ordinarily result in an unusually thoughtful and detailed consideration of the system on the part of the men who are operating it. The effort to interpret and account for results, and the resulting further tests, will frequently uncover unsuspected conditions quite different from those which originally suggested the tests.

Acknowledgment—At the request of WATER WORKS AND SEWERAGE, the author has revised and added to an article published by him (Journal of the A. W. W. A. for July, 1930), on the same subject. We believe the practical value of this contribution justifies its re-publication.—*Editor.*

[*See also "Pipe Flow Diagram" and "Flow Powergraph" which appear in Part III.*]

Fire Flows Required for Towns of Various Sizes, by National Board of Underwriters

Population	Required Fire Flow, Gallons per Minute for Average City
1,000	1,000
2,000	1,500
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000
125,000	10,000
150,000	11,000
200,000	12,000

Over 200,000 population, 12,000 gallons a minute, with 2,000 to 8,000 gallons additional for a second fire.

In residential districts the required fire flow depends upon the character and congestion of the buildings. Sections where buildings are small and of low height and with about one-third the lots in a block built upon, require not less than 500 gallons a minute; with larger or higher buildings up to 1,000 gallons is required, and where the district is closely built, or buildings approach the dimension of hotels or high value residences, 1,500 to 3,000 gallons is required, with up to 6,000 gallons in densely built sections of 3-story buildings.

(*See also table of "Effective Fire Streams," page 191.

Commercial Pipe Sizes for Fire Streams*

Number of 1 1/4-Inch Hose Nozzles	Ordinary Fire Streams											
	40 Pounds Pressure		50 Pounds Pressure		60 Pounds Pressure		70 Pounds Pressure		80 Pounds Pressure		90 Pounds Pressure	
	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.	Required Size Pipe Ins.	Flow Cu. Ft. per Min.
1	4	20	6	23	6	25	6	27	6	29	6	30
2	6	40	8	45	8	50	8	53	8	57	8	61
3	8	61	8	68	10	74	10	80	10	86	10	91
4	10	81	10	90	10	99	10	107	12	114	12	121
5	10	101	12	113	12	124	12	134	12	143	12	152
6	12	121	12	135	12	149	14	160	14	172	14	182
7	12	141	14	158	14	174	14	187	14	200	16	212
8	12	162	14	181	14	199	16	214	16	229	16	242
9	14	182	14	203	16	223	16	241	16	257	18	273
10	14	202	16	226	16	248	16	267	18	286	18	303
11	16	222	16	248	18	273	18	294	18	314	18	333
12	16	243	18	271	18	298	18	321	20	343	20	364
13	16	263	18	293	18	323	20	348	20	372	20	394
14	18	283	18	316	20	348	20	374	20	400	20	424
15	18	303	20	339	20	372	20	401	20	429	24	455
	High-Pressure Fire Streams											
	100 Pounds Pressure		110 Pounds Pressure		120 Pounds Pressure		130 Pounds Pressure		140 Pounds Pressure		150 Pounds Pressure	
1	6	32	6	33	6	35	6	36	6	38	6	39
2	8	64	8	67	10	70	10	73	10	75	10	78
3	10	96	10	100	10	105	10	109	12	113	12	117
4	12	128	12	134	12	140	12	145	12	151	14	156
5	14	160	14	167	14	174	14	181	14	188	14	195
6	14	191	14	200	14	209	16	218	16	226	16	234
7	16	223	16	234	16	244	16	254	16	264	18	273
8	16	255	16	267	16	279	18	290	18	301	18	313
9	18	287	18	301	18	314	18	326	18	339	20	352
10	18	319	18	334	20	349	20	363	20	377	20	391
11	20	351	20	367	20	384	20	399	20	414	20	430
12	20	383	20	401	20	419	20	435	24	452	24	469
13	20	415	20	424	24	454	24	472	24	490	24	508
14	24	447	24	467	24	488	24	508	24	528	24	547
15	24	479	24	501	24	523	24	544	24	565	24	586

To convert cubic feet to gallons, multiply by 7.4805.

In calculating above table, the following assumptions were made: Nozzles, 1 1/4-inch smooth bore, playing simultaneously, and attached to 200 feet of best quality rubber-lined hose; pressures measured at hose connections; velocity of water in pipe approximately 3 feet per second.

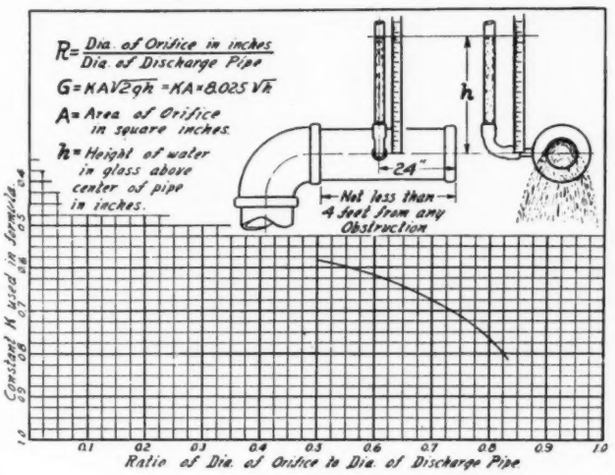
*Reproduced by courtesy of N. S. Hill, Jr.

MEASURING FLOWS By THE ORIFICE METHOD

The orifice method is a simple way to measure flow of water from a pipe discharging horizontally into the open air. The sketch shows the general arrangement.

A plate or cap is affixed to the end of the pipe with the circular orifice in the exact center of the pipe. The size of orifice should be from one-half to three-quarters of the size of the pipe, but must be of such size that it will run full of water.

A hole for ⅛-in. pipe should be drilled and tapped 24 in. back from the orifice and a short ⅛-in. nipple screwed in until the inner end is exactly flush with the inner wall of the pipe. One end of a piece of rubber hose



is slipped over the end of the nipple and the other end over a glass tube, which should be supported in a vertical position.

Ratio R is the diameter of the orifice divided by the inside diameter of the pipe, and the proper value of K is found from the curve. In the formula A is figured as the area of the orifice in square inches, G = 32.2, and H is read as the height in inches of the water in the glass tube above the center of the pipe. Gallons per minute (g) then can be figured.

For convenience hen determining capacities during pumping tests, the accompanying table for various orifices commonly employed will prove useful.

ORIFICE TABLE FOR DETERMINING WATER FLOW

[Compiled by the Engineering Department of Layne and Bowler, Inc., from original calibrations made in the Hydraulics Laboratories at Purdue University.]

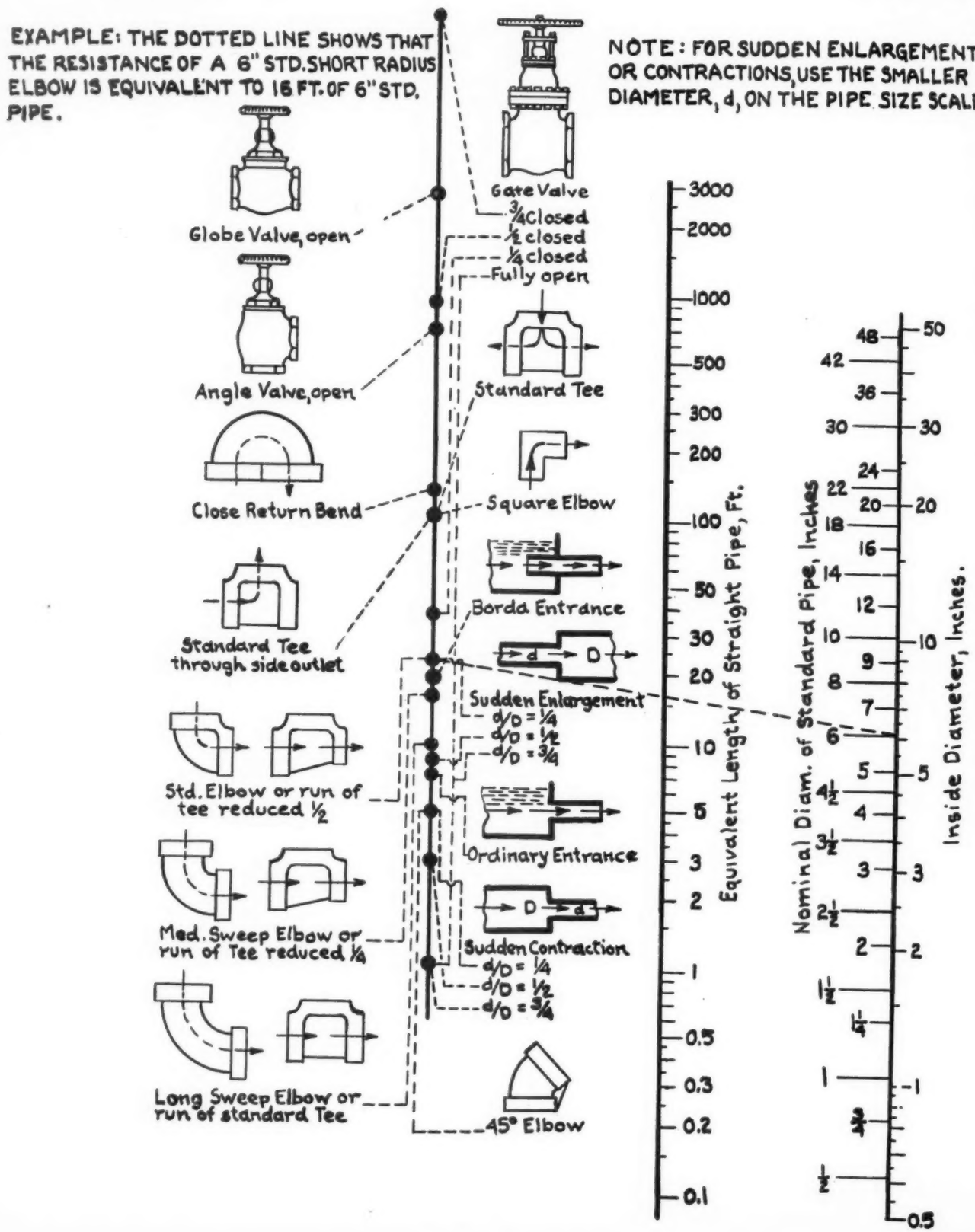
Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	Head in Inches
	4 in. Pipe	6 in Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	10 in. Pipe	10 in. Pipe	
5	100	76	145	140	280	220	380	320			5
5.5	104	79	153	145	293	230	394	333			5.5
6	108	82	160	150	305	240	408	345			6
6.5	111	85	167	155	316	250	421	358			6.5
7	115	88	172	160	328	260	433	370			7
7.5	119	91	179	165	339	270	446	383			7.5
8	122	94	185	170	350	280	458	395	600	935	8
8.5	125	96	190	175	361	289	471	408	617	963	8.5
9	128	99	195	180	372	298	483	420	633	992	9
9.5	130	102	200	185	383	307	495	433	650	1016	9.5
10	133	104	205	190	391	316	508	445	666	1040	10
10.5	137	107	210	195	402	324	521	458	682	1060	10.5
11	140	109	215	200	412	330	533	470	698	1080	11
11.5	143	111	220	204	421	338	545	480	713	1100	11.5
12	146	114	225	208	430	346	556	490	728	1120	12
12.5	149	116	230	212	439	354	567	500	743	1139	12.5
13	151	118	234	216	448	362	578	510	757	1158	13
13.5	154	121	239	219	457	369	589	520	771	1176	13.5
14	157	123	243	224	465	376	599	530	785	1194	14
14.5	159	126	247	227	473	383	609	540	799	1212	14.5
15	162	128	250	231	480	390	618	550	812	1230	15
15.5	164	130	254	234	488	396	627	559	825	1248	15.5
16	167	132	257	238	495	402	636	568	838	1266	16
16.5	170	134	261	241	503	408	645	577	851	1284	16.5
17	172	136	264	245	510	414	654	586	863	1302	17
17.5	175	138	268	249	517	420	663	595	875	1319	17.5
18	178	140	271	252	524	426	672	604	887	1336	18
18.5	180	142	275	256	530	432	681	612	899	1351	18.5
19	183	144	278	259	536	438	690	620	910	1370	19
19.5	185	146	282	263	542	444	699	628	922	1387	19.5
20	187	148	285	266	548	449	708	636	933	1404	20
20.5	190	150	289	270	554	455	717	643	945	1421	20.5
21	192	152	292	273	560	460	726	650	956	1438	21
21.5	195	154	296	275	566	465	735	657	968	1455	21.5
22	197	156	299	279	572	470	744	664	979	1471	22
22.5	199	158	302	282	578	475	752	671	990	1486	22.5
23	201	160	305	285	584	479	760	678	1001	1500	23
23.5	203	162	307	288	590	484	768	685	1012	1515	23.5
24	205	164	310	291	596	488	776	692	1022	1529	24
24.5	207	165	314	294	602	492	784	699	1033	1543	24.5
25	210	167	317	297	608	496	791	706	1043	1557	25
25.5	212	169	320	300	614	500	798	713	1059	1571	25.5
26	214	171	323	303	620	504	805	720	1064	1585	26
26.5	216	173	326	305	626	508	812	727	1074	1599	26.5
27	219	174	329	308	632	512	818	734	1084	1613	27
27.5	221	176	332	311	638	516	825	741	1094	1627	27.5
28	222	177	335	314	644	520	831	747	1104	1641	28
28.5	224	179	337	317	650	524	838	754	1114	1655	28.5
29	226	180	340	320	656	528	844	760	1124	1669	29
29.5	228	182	343	323	662	532	851	767	1134	1683	29.5
30	230	183	346	325	668	536	857	773	1143	1697	30
30.5	232	185	348	328	674	540	863	780	1153	1711	30.5
31	234	186	351	330	680	544	869	786	1162	1725	31
31.5	236	188	354	333	686	548	876	793	1172	1739	31.5
32	239	189	357	335	692	552	882	799	1181	1753	32
32.5	240	191	360	338	697	556	889	806	1191	1767	32.5
33	242	192	363	340	703	560	895	812	1200	1791	33
33.5	244	194	366	342	709	564	901	818	1209	1795	33.5
34	246	195	369	345	715	568	907	824	1218	1809	34
34.5	248	196	372	347	720	572	913	830	1227	1823	34.5
35	250	197	375	349	726	576	919	836	1235	1837	35
35.5	252	198	377	351	732	580	925	842	1243	1851	35.5
36	254	200	380	354	737	584	931	847	1251	1865	36

Head in Inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		Head in Inches
	4 in. Pipe	6 in. Pipe	6 in. Pipe	8 in. Pipe	6 in. Pipe	8 in. Pipe	8 in. Pipe	10 in. Pipe	
36.5	256	201	383	356	743	588	937	852	36.5
37	257	203	385	358	748	592	943	857	37
37.5	259	204	388	360	754	596	949	862	37.5
38	260	205	390	363	759	600	955	867	38
38.5	262	206	393	365	765	604	961	872	38.5
39	263	208	396	367	770	608	967	877	39
39.5	265	209	398	369	776	612	974	882	39.5
40	266	210	401	371	781	616	979	887	40
40.5	267	211	403	373	786	620	985	891	40.5
41	269	212	406	375	790	624	990	896	41
41.5	271	213	408	378	795	628	996	901	41.5
42	272	214	411	380	800	631	1001	906	42
42.5	274	216	413	382	805	635	1007	910	42.5
43	275	217	415	384	810	638	1012	915	43
43.5	277	218	418	386	815	642	1018	920	43.5
44	278	219	420	388	820	645	1023	925	44
44.5	280	220	422	390	824	649	1029	929	44.5
45	281	222	425	392	828	652	1034	934	45
45.5	283	223	427	394	832	656	1040	939	45.5
46	284	224	429	396	837	659	1045	944	46
46.5	285	225	432	399	842	663	1051	948	46.5
47	287	227	434	401	847	666	1056	953	47
47.5	289	228	437	403	851	669	1062	958	47.5
48	290	229	440	405	855	672	1067	963	48
48.5	292	230	442	407	859	676	1073	967	48.5
49	293	231	444	409	863	679	1078	972	49
49.5	294	232	446	411	868	683	1084	977	49.5
50	296	234	448	413	872	686	1089	982	50
50.5	298	235	450	415	876	690	1095	986	50.5
51	300	236	453	417	880	693	1100	991	51
51.5	301	237	455	419	884	697	1105	996	51.5
52	302	238	457	421	888	700	1110	1000	52
52.5	303	239	459	423	892	704	1115	1005	52.5
53	304	240	461	425	896	707	1120	1009	53
53.5	305	241	463	427	900	711	1125	1014	53.5
54	307	243	465	429	904	714	1130	1018	54
54.5	309	244	467	431	908	718	1135	1023	54.5
55	310	246	469	433	912	721	1140	1027	55
55.5	311	247	471	435	915	725	1145	1032	55.5
56	313	248	472	437	919	727	1150	1036	56
56.5	314	249	474	439	923	730	1155	1040	56.5
57	315	250	476	441	927	733	1160	1044	57
57.5	316	251	478	443	930	736	1165	1046	57.5
58	317	252	480	445	934	739	1170	1052	58
58.5	319	253	482	447	938	742	1175	1056	58.5
59	320	254	485	449	942	745	1180	1060	59
59.5	321	256	487	451	945	748	1185	1064	59.5
60	323	257	489	453	948	751	1190	1068	60
60.5	324	258	491	455	951	754	1195	1072	60.5
61	325	259	492	457	955	757	1200	1076	61
61.5	326	261	494	459	958	760	1205	1080	61.5
62	328	262	496	461	961	763	1209	1084	62
62.5	329	263	498	463	964	766	1214	1088	62.5
63	330	264	500	465	968	769	1218	1092	63
63.5	331	265	502	467	971	772	1223	1096	63.5
64	333	266	504	469	974	775	1227	1099	64
64.5	334	267	507	471	977	778	1232	1103	64.5
65	335	268	509	472	981	781	1236	1106	65
65.5	336	269	511	474	984	784	1241	1110	65.5
66	338	271	513	475	988	787	1245	1113	66
66.5	339	272	515	477	991	790	1250	1117	66.5
67	340	273	517	479	995	793	1254	1120	67
68	343	275	520	483	1002	799	1263	1127	68
70	349	280	525	491	1016	811	1280	1140	70

Courtesy of Layne & Bowler, Inc.

RESISTANCE OF VALVES AND FITTINGS TO FLOW OF WATER*

When the flow of a fluid in a pipe line is altered by some obstruction such as a valve or fitting, the velocity is changed, turbulence is magnified and a drop in pressure results. This pressure drop may be insignificant in long lines where it is very small in comparison to the total drop, but when the line is short the pressure drop through valves and fittings becomes



a major item in the total pressure drop value.

The most widely used data on the subject of the resistance of valves and fittings to the flow of water and steam is the information given in Dean Foster's paper on "Effect of Fittings on Flow of Fluids Through Pipe Lines" published in Vol. 42, 1920, of the Transactions of the American Society of Mechanical Engineers. Recently, tests conducted by others have indicated that the values given by Foster are low for globe valves, angle valves, etc., and that data is needed to establish the correct information to use. It has been the tendency, and probably is the most practical way, to present the friction values in terms of an equivalent length of the same size of pipe; i.e., the pressure drop caused by a 2-inch elbow is equivalent to approximately the pressure drop caused by five or six feet of 2-inch pipe under the same conditions of flow.

Realizing the need for definite data covering this subject, Crane Co. has recently conducted pressure drop tests on valves and fittings on both water and steam. These tests were made on 2 inch and 6 inch sizes and conducted under conditions which were thoroughly investigated previous to the tests. The results of these tests are presented herewith together with a description of the method used in conducting them.

[*Note.*—Water and steam can be treated comparatively and a relation can be established between the relative friction values of water and steam. Foster has stated that the equivalent length of pipe for steam flow is about .8 of that established for the flow of water.]

Friction Losses of Water Line Valves and Fittings

The tests for determining the pressure drop of valves and fittings installed in a water line were made in the following manner:

A flow nozzle was installed in a 3 in. test line leading from the bottom of a 1,000 gallon water tank. A mercury manometer was set across this nozzle and the relation of mercury deflection to the gallons of water per minute flowing through the pipe was determined. The flow through the pipe was thereafter noted only in terms of mercury deflection which was readily transposed into gallons per minute by reference to the calibration chart.

The valve or fitting to be tested was placed in the line at some distance from the flow nozzle and the flow water through it was regulated by a throttling valve situated at the outlet of the line. The pressure drop was measured by means of a mercury manometer, or where the deflection was too great, by two sensitive low pressure gages, the leads of which were situated in the test line at a distance of ten pipe diameters (20 in.) from each end of the valve or fitting on test. The initial pressure at the inlet of the test line was kept constant at 80 pounds per square inch and the various rates of flow produced by throttling the outlet of the test line.

After the data was obtained the means of presenting it in its best form was investigated. In any pressure drop tabulation, the values for the fittings and valves in the line are added to the pressure drop of the entire length of line. Therefore, it seemed reasonable to disregard the pressure drop caused by the length of the valve or fitting and just list the pressure drop which was added to the line due to the presence of the article.

For instance, if a valve 4 in. face to face is installed in a line 30 in. long, the actual pressure drop through the valve will be the total pressure drop minus the pressure drop caused by 26 in. of pipe. However, in a practical problem this value will be added to the pressure drop caused by the total length of the line which will give a pressure drop value slightly higher than the actual. This may not be so noticeable with one or two valves or fittings in the line, but where the number runs up into 10 or 20 the added drop may be considerable.

This "No-length" concept was established and has been used before with reference to elbows in "The Friction of Water in Pipes and Fittings" by F. E. Giesecke, University of Texas Bulletin No. 1759.

Resistance in Terms of Equivalent Pipe Length

From data given in the tests conducted by Crane Co. and also from information gathered from authentic sources, Fig. 16, has been prepared which gives the equivalent length of pipe to produce the same pressure drop as a valve or fitting. This additional pipe length should be added to the length of the line in order to determine the total pressure drop.

*From Crane Co.'s "Engineering Data on Flow of Fluids in Pipes"—Technical Bulletin No. 405—1935. Parts dealing with steam pressure losses have been omitted.—Ed.

The equivalent length of pipe has been based upon the pressure drop values for the flow of water in pipes and upon the following coefficients of

$$H_1 = k\frac{V^2}{2g}$$

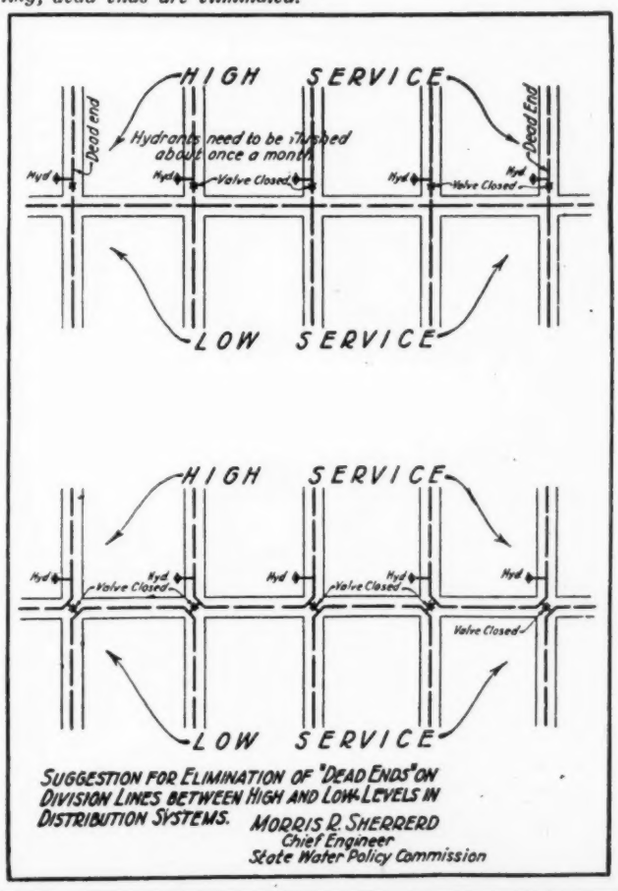
H_1 = Loss of head in ft.
k = Coefficient
V = Vel. in ft. per sec.
$2g = 64.4$

Type	*Coefficient*	*Authority*
Globe valves	10	Crane Tests
Angle Valve	5	Crane Tests
Return Bend	2.2	
Tee	1.8	Giesecke & Bladgett—Texas College
Short Radius Elbow	.9	Giesecke & Bladgett—Texas College
Med. Radius Elbow	.75	& Crane tests
Long Radius Elbow	.60	Bulletin No. 2712—U. of Texas.
Gate Valve (Open)	.19	Bulletin No. 252—U. of Wis. (Av.)
¼ Closed	1.15	Bulletin No. 252—U. of Wis. (Av.)
½ Closed	5.6	Bulletin No. 252—U. of Wis. (Av.)
¾ Closed	24.0	Bulletin No. 252—U. of Wis. (Av.)
Borda Entrance	.83	"Hydraulic" Daugherty (Average)
Sudden Enlargement		
d/D — ¼	.92	"Hydraulics" Daugherty
d/D — ½	.56	"Hydraulics" Daugherty
d/D — ¾	.19	"Hydraulics" Daugherty
Ordinary Entrance	.5	"Hydraulics" Daugherty
Sudden Contraction		
4/D = ¼	.42	"Hydraulics" Daugherty
d/D = ½	.33	"Hydraulics" Daugherty
d/D = ¾	.19	"Hydraulics" Daugherty
45° Elbow	.42	Bulletin No. 2712U. of Texas

ONE METHOD OF ELIMINATING DEAD ENDS

A means of eliminating dead ends of water mains where there are two types of water service, has been developed by Morris R. Sherrerd, Chief Engineer, New Jersey State Water Policy Commission.

The lower part of the illustration shows how by having a short gated connection between the two services, and by running the main around the block or square without using a cross fitting, dead ends are eliminated.



SUGGESTION FOR ELIMINATION OF "DEAD ENDS" ON DIVISION LINES BETWEEN HIGH AND LOW-LEVELS IN DISTRIBUTION SYSTEMS. MORRIS R. SHERRERD Chief Engineer State Water Policy Commission

PRACTICAL ELECTRICITY IN THE PLANT

The A. B. C.'s of Electricity for the Water and Sewage Works Man

By MARSDEN C. SMITH

Engineer and Supt. Water and Electricity, Department Public Utilities, Richmond, Va.

Taken from a series of short articles by Mr. Smith, dealing with the A.B.C.'s of practical electricity for water works and sewage plant operators.

The author, a graduate electrical engineer, is a well known water works operator. He is, thereby, peculiarly well qualified to present these discussions, which should be of considerable benefit to operators and designers less thoroughly grounded in electrical matters.

If there are points in his contributions not clear to the reader, Mr. Smith offers to answer inquiries.

THE increasing use of electricity in water and sewage treatment plants produces problems of design, operation and maintenance with which the engineer in charge is generally but little familiar. Fortunately, while advanced electrical engineering is a very involved subject, a helpful and useful knowledge of its fundamental principles can be obtained quite readily by the trained personnel of such plant. To that limited end the presentation of this series of articles is confined.

PART I—ELECTRICAL UNITS

The Volt

One of the most important units of electricity is the Volt. It is the unit of electrical *pressure.* Just as we measure water force or pressure in units of pounds per square inch or feet of head, the unit of electromotive (electric moving) force is the volt. In equations, its symbol is E. Voltage is sometimes expressed in print as the emf—abbreviation for electric-motive force.

Standard voltages are 110, 220, 440, 2,200, 4,000, and 13,200. The individual for whom these articles are intended is rarely concerned with voltages in excess of 2,200. Furthermore, the 110 volt standard is now in the process of change, and seems to be quite generally replaced by a standard of 120 volts.

Extra-heavy fittings and greater precautions are necessary with greater water pressures; so too, must greater care be taken both of life and property when higher electrical pressures are used. However, pressures of as little as 110 volts, in common domestic use, may prove fatal and care should always be taken to avoid personal contact with even these relatively low pressure circuits.

Most electrical apparatus is designed to operate at one of the above mentioned standard voltages. The use of other than these standards is both unnecessary and uneconomical. Incandescent lamps are generally rated at from 110 to 125 volts in five-volt increments. They may be obtained designed for 220 volts, but such lamps are not recommended except where no 110-volt service is available. Even then safety and economy demand the use of 110-volt lamps if possible.

Some Practical Considerations

Lamps are very sensitive to voltage change; and the operator should see that the lamps are purchased for the circuits on which they are to be used. For example, if the average voltage at the station is known to be 118 volts, 120-volt lamps should be used. Here the use of 110-volt lamps would increase the lamp replacement cost by almost 300 per cent.

Motors are not nearly so sensitive to voltage change as are lamps and will operate successfully at applied voltages within 10 per cent above or below normal rated voltage. Greater voltage variation will generally cause excessive heating and unsuccessful operation.

Small motors (less than 5 horse-power) are usually single phase and operate at standard lamp voltages. Large motors, 5 to 50 H.P., are cheaper when designed for 220 or 440 volts. Larger than 50 H.P. should be designed for 2,200 volts. Of course, local conditions may change these recommendations. One large plant has motors from 3 to 300 H.P. The station designers used 2,200 to 440-volt transformers; motors between 50 to 300 H.P. were ordered for 440 volts. A second set of transformers reduced the 440 volts to 220 volts for the smaller motors (up to 50 H.P.). Certainly this is unfortunate, because the larger and more expensive motors would have been of less first cost if designed for 2,200 volts, and the 2 to 5 per cent transformer losses, which materially increases operating costs, would have been saved. The smaller motors could all have been 440-volt type, thus here again would have been saved the second transformer losses. Here we see an evident error that a better understanding of the problem of electricity in design would have avoided.

Other than electrical engineers often fear the use of 2,200 volts. It is true, that there is no need for this higher potential, unless the size and number of motors justifies its use. However, where the total of as much as two or three hundred horse-power is required for motors larger than 50 H.P., the higher potentials are certainly advisable.

The relative advantage of the use of 220 or 440 volts as the operating voltage for the smaller motors is not so definite. However, for larger plants 440 volts seems more desirable. Safety requires the same care with 220 volts as with 440 volts, and a much wider range of motor sizes can be more economically operated at this than at 220 volts.

The Ampere

The second important unit of electricity to be considered is the Ampere.

It is the unit of electrical *rate of flow.* We are familiar with the various measures of the rate of flow of liquids; gallons per minute, etc.; so we should think of the unit rate of flow of electricity as the ampere. In equations its symbol is generally (I). In print Amperes are sometimes abbreviated to "Amp." Larger pipes are required to carry larger rates of flow of water economically; so too, larger wires are needed to carry larger currents (amperes) economically. Small pipes may be uneconomical because friction causes too great loss of water pressure. In exactly the same way, wires may be too small for the amperage (current flow) and cause an uneconomical loss of electrical pressure (voltage drop).

There are no standard currents as in the case for the voltage rating of electrical apparatus. Each appliance, lamps, heating devices, etc., takes from the circuit a current dependent upon its design and lack of resistance to flow. Motors require, for example, a current that varies with the load. All electrical apparatus (except lamps) should have its normal current rating stamped upon its nameplate. Lamp current is determined by dividing its watt rating by its rated voltage.

However, there are certain appliances such as wire, fuses and switches that are rated in terms of the current they may safely carry; thus currents are to this extent standardized. The plant manager should realize that these current ratings are fixed by the National Electric Code, and he should not permit greater current to flow through accessories than the limits established by this code. Oftentimes circuits are fused far beyond the rated capacity of the wire, which is supposedly being protected by the fuse. Such practice is both uneconomical and dangerous.

Most appliances, including motors, are connected between the supply lines, that is, in parallel. In this way the circuit voltage is impressed upon each appliance, causing a current to flow through the appliance of a quantity dependent upon its rating and load. These increments of current are added, hence the supply wires carry greater and greater total current as we work back toward the source of power. For example: Five 1,000-watt

lamps rated 100 volts each require 10 amperes. Let us designate these as numbers one to five, from that nearest the supply to the most remote. Both wires between the supply and the first (No. 1) lamp carry 50 amperes; between 1 and 2, 40 amperes, and so on until between 4 and 5 the current has reduced to 10 amperes, or that required by No. 5—the last lamp. They all have (practically) the same voltages as the supply applied to their terminals.

Some Practical Considerations

When installing new apparatus there are two considerations of great importance: (1) Use wire of ample conductor size. (2) Employ insulation having a large factor of safety. For low potential circuits (less than 600 volts) 30 per cent pure rubber insulation will generally prove more economical than the standard code insulation. Particularly is this true in water and sewage treatment plants due to the prevalence of dampness in such locations. For 2,200-volt circuits rubber insulated cable is more easily installed than is varnished cambric cables. Rubber depreciates must more rapidly when subjected to heat and grease or oil than does varnished cambric, but it is less affected by moisture. For this reason, varnished cambric is never used without some form of outer coating, usually lead. Modern synthetic resins and other compounds are rapidly proving their value for use as the outer protective coating, materially lessening the installation difficulties. These coatings are deserving of consideration.

In general, where expert electrical maintenance is not available, the proper thickness of 30 per cent pure-rubber insulation, on conductors of adequate size for the current they will ever have to carry, will certainly well repay the increased investment cost. Where such expert maintenance is available, varnished cambric insulation may prove better for 2,200-volt circuits.

The Ohm

The unit of electrical resistance is the Ohm. In equations its symbol is (R).

If we close the spigot, even though there be water pressure at the valve, no water can flow because the resistance is too great. The same result is obtained when opening an electric switch; the pressure (voltage) still exists but the resistance (ohms) become so great that no current (amperes) can flow. This is an example of localized resistance.

Electrical resistance may be distributed, in fact *is* distributed along the conductor just as is the pipe resistance to water flow proportional to its size, length and condition. Fortunately, in electrical circuits the loss of voltage (pressure) is always directly proportional to the resistance and rate of current flow. Therefore, the loss of power (to be discussed in the next article) is proportional to the resistance and the square of the rate of flow or current.

An electrical device, such as a lamp, does not use or destroy current in the sense that an oil lamp consumes oil, but by its relatively high resistance limits the current that may flow as a result of the impressed electromotive force—voltage. Thus we have the simple but important equation known as Ohm's Law:

$$E = RI \quad \ldots\ldots (1)$$

There are no standards of resistance; however, the established resistance per unit length of electrical conductors and resistance alloys may be found in any electrical engineer's handbook.

Direct vs. Alternating Current

Formula (1) applies to circuits that contain resistance only, or in which the frequency is zero, as in the case of direct current. This term frequency must now be understood. If the polarity between two wires (A and B) of a circuit is not changed, the current flow will always be in one direction in the wires, thus constituting what is termed direct-current—(D.C.). If we alternate wires A and B from one side of the source to the other, once each ½ second, the direction of current flow in A and B will reverse once every ½ second, and will begin to flow in the original or *same* direction in a given conductor once every second. Electrically we would say that there was being produced "An electromotive force (current) having a frequency of one cycle per second." Fundamentally that is the difference between alternating and direct currents. Modern alternating currents closely follow the sine law in their time-potential value; and the standard frequency in this country is now sixty cycles per second.

When direct current is applied to a coil of copper or other wire (having resistance R) wound around iron, if the current and voltage be carefully measured, equation 1 will be found to apply. When an alternating voltage is applied this equation no longer can be used. This is because any magnetic circuit is an inductive circuit, and the effect of an inductance is to divide the alternating current into two components which are at right angles to one another. Hence to obtain the same current through the coil when an alternating voltage is applied, a greater voltage is required than when a direct voltage is used. So for alternating current circuits equation 1 becomes:

$$E = ZI \quad \ldots\ldots (2)$$

in which Z is the impedance of the circuit.

Many devices, such as heating appliances and lamps have little or no inductance; hence may be used on either direct or alternating current circuits of the rated voltage; but inductive devices, such as transformers and motors, cannot be used on direct current circuits unless especially designed for the purpose.

Transformers

The engineer for whom these articles are intended rarely is concerned with the use of transformers; however, a brief discussion of them is advisable. The standard transformer consists of two stationary coils of wire insulated from one another and wound around a common iron core. A special class, the auto-transformer, commonly used for motor starters, has only one winding with connections to some desired turn between the two end turns.

Of the winding in the auto-transformers, the turns connected to the power supply is the primary; the secondary winding is connected to the load. The voltage change between the primary and secondary is in direct ratio to the number of turns used in the two windings; conversely, the current is in the inverse ratio to the number of turns. Hence a transformer may be used to increase voltage as readily as to reduce it—the so-called "step-down." Many deaths have resulted from opening the high voltage switch, assuming the transformer "dead," when in fact the 110-volt side was still energized thus producing normal high voltage in the primary.

Instrument transformers are especially designed to accurately reduce the potential or current, as the case may be, for metering and other purposes. Care should be taken to always connect the secondary terminals of current transformers together with wire (short-circuit them) if the secondary circuit must be disconnected for any purpose while the primary continues to carry current.

It is well to know that transformers, if kept cool enough, can safely carry much greater than rated loads. Cold winter weather and artificial ventilation around the tanks is effective, but hot locations and days are dangerous. Tank temperatures should never exceed 90 degrees C. Contamination of the oil by dirt or even traces of moisture must be avoided. In larger units the oil should be examined monthly by a competent inspector.

The Watt

Another very important unit of electricity is the Watt, which is the unit of electrical power. The more commonly used unit is the Kilowatt, which is one thousand watts. The symbol for the Watt is (W); for the Kilowatt (KW). The mechanical unit of power is horse-power; one horse-power (H.P.) is the equivalent of 746 watts or 0.746 kilowatts. Due to the fact that the efficiency of small motors is approximately 75 per cent, the input in kilowatts is, by coincidence, closely the same as the mechanical output in horse-power.

With direct current, electrical power is the product of the current (I) and the voltage (E). Thus we have:

$$P = EI \quad \ldots\ldots (3)$$

However, substituting for (E) from equation (1), wherein $E = RI$, we have:

$$P = RI^2 \quad \ldots\ldots (4)$$

Or similarly, substituting for (I) where $I = \frac{E}{R}$ in the same equation:

$$P = \frac{E^2}{R} \quad \ldots\ldots (5)$$

Now, it becomes evident that electrical power varies directly with both current and voltage, if resistance is not considered, but as the square of either (E or I) if the resistance is considered.

PART 2

POWER FACTOR; ITS SIGNIFICANCE

With alternating currents equation (3) becomes the more familiar form, and—

$$P = EI \cos \theta \quad \ldots\ldots (6)$$

In this equation the Cos θ is designated as the power-factor. If an alternating current circuit contains resistance only (no capacity or inductance) the angle θ becomes zero; hence, its

cosine, which is the power-factor becomes unity. Electrical installations in water and sewage treatment plants rarely contain sufficient capacity (condenser action) to be of any practical effect, hence we may omit further reference to "capacity" in these articles. Inductance, however, is of great importance, and in practical installations may reduce the power factor as much as 30 per cent.

The actual mathematical value of the power-factor of practical circuits is difficult to compute; however, it is well for the engineer to have some idea as to the values that may be expected. Incandescent lamps and heating devices, since they contain but little inductance, are virtually non-inductive; hence, their power-factor closely approaches unity. Motors and transformers vary through very wide limits. Of course, a transformer being highly inductive when delivering no load, its power-factor is quite near zero; but, at rated load the power-factor becomes quite nearly that of the circuit being supplied by the transformer. Small motors, up to 5 h.p., require power at not more than 60 per cent power-factor; particularly so when operating at light loads. Large induction motors, at full load, now may operate at as high as 94 per cent; and, synchronous motors, more fully discussed in coming articles, may be operated almost as desired.

The objection to low power-factors is that larger currents are required for the same power, thus increasing power losses in the whole electrical system. Furthermore, low power-factors cause much wider voltage variations than do greater loads with higher power-factors. For this reason many power companies offer reduced rates to those consumers whose apparatus constitutes a load having a favorable power-factor. This fact may be of value to many larger operators. It is true, however, that plant operators can exercise but limited control over the power-factor of their stations except through the selection and operation of the motors. This phase of the subject will be later discussed when motors and their characteristics are considered.

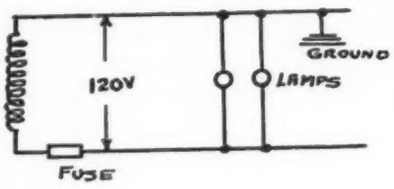


FIG 1

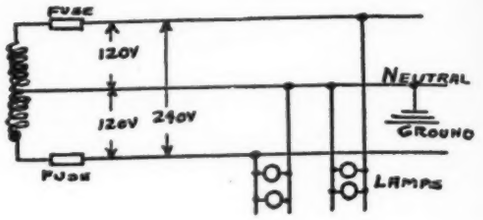


FIG 2

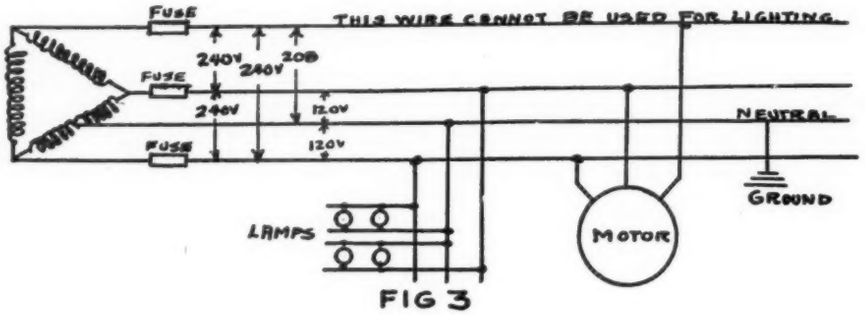


FIG 3

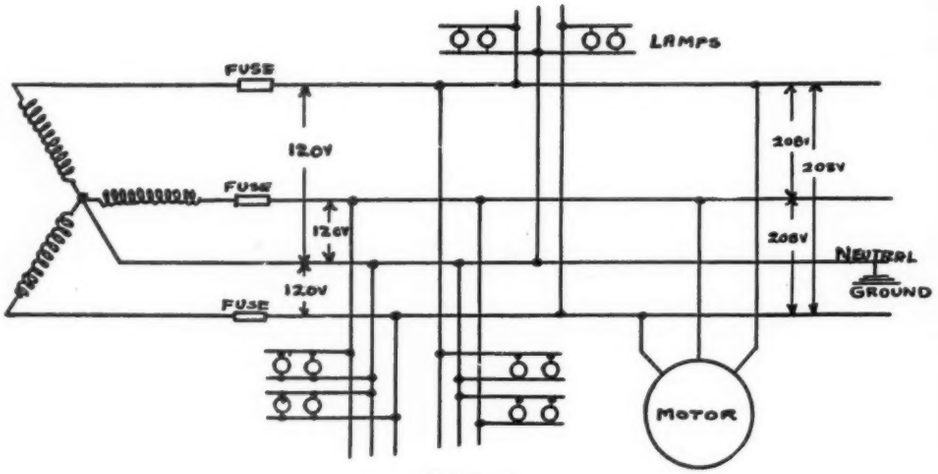


FIG 4

Circuits: *Figs.* 1, 2, 3 *and* 4

The Kilowatt-Hour

The kilowatt-hour (KwHr) is the unit by which electric power is generally sold. As its name implies, it is the average power consumed, in kilowatts, multiplied by the number of hours involved. For example: if an electric iron is operated for two hours at average rating of 600 watts, there is used $600 \times 2 = 1200$ watt-hours, or 1.2 KwHrs.

The volt-ampere (VA) is the product of the volts and amperes of a circuit or an appliance, without reference to power. Thus, the transformer is always rated in kilo-volt-amperes (KVA) because its parts can be designed for the voltage and current value desired, but the power-factor of its load may vary through wide limits. Thus we see that:

$$KW = KVA \times \text{Cos } \theta \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Hence, if we are to know the safe load for a transformer rated at 100 KVA, we must first determine the power-factor of the load to be connected. If we may assume the load to be one-half lamps and one-half small motors; we may approximate the average power-factor to be 82 per cent. Hence, by equation (7) we find Kw $= 100 \times 0.82$ (82 Kw) to be the safe load for this case.

The Cos θ, which we now recognize to be the power-factor, is actually the cosine of the angle of time-phase displacement between the current and the voltage of an alternating current circuit containing "capacity" or inductance.

Circuits

The term, "phase," is also applied to designate the circuits of an alternating current system. In the "Single-Phase" system the *voltages* are in the same time-phase in all parts of the system. In the "Two-Phase" system, the two voltages are 90 degrees apart. In the "Three-Phase" system they are 120 degrees apart.

In another sense, there are in effect one or two or three circuits in the single, the two or the three-phase systems. Of course, the power-factor may be different in each phase; hence the currents in the phases may not be of exactly the same angular difference as the voltages producing these currents.

The simplest circuit is that comprising the single-phase (two-wire) system, as in Fig. 1. This is used for the final branch circuit of larger systems, and in case of small loads, including most residences, it is always used.

The single-phase, three-wire system is next in capacity and in frequency of use. Single-phase, two-wire branches are connected thereto as shown in Fig. 2. The evident advantage of three wires over the two-wire system is that when loads are

balanced, the neutral carries no return current, hence the lamps and appliances operate at 120 volts, whereas the circuit operates at 240 volts. In this way twice as much power can be carried over the same wires, by merely adding one additional wire.

Grounding Practice

The neutral must be grounded. It should be the same size as the phase wires; and, it must *not* be fused or connected to any switch, and the wire used for the neutral must have white covering for identification, and the neutral must be connected to the white screw in all receptacles. In the single-phase, two-wire system one of the wires must be grounded and the same rules as given for the neutral conductor wire must be observed.

(Grounding practice as it affects water works piping will be given some discussion at a later point in this article.)

Three-Phase Standard for Heavy Duty

The three-phase (three-wire) system is standard for motor loads. If lighting is required, the neutral of one transformer (made larger to carry the additional load) is brought out as in Fig. 3. Most power companies limit the single-phase load that may thus be supplied to 50 KVA. In addition, this method of supplying the lighting loads makes service interruptions more frequent because of the necessity for grounding one of the transformer windings. Perhaps most serious of all is the objectionable flicker in the lights obtained when starting motors, particularly elevators connected to the system. Of course, economy often rules and hence this system is frequently used; but unless the motors are relatively small, and are started very infrequently; it is undoubtedly better to separate the lighting and very small motors from the power system.

The formula for power in the different systems, with balanced load, is given in the following table:

System	*Power*		*Max. Volts to Ground*
Single-Phase (Two-Wire)	$P = EI\cos\theta$	Here E=120	120
Single-Phase (Three-Wire)	$P = EI\cos\theta$	Here E=240	120
Two-Phase (Four-Wire)	$P = 2EI\cos\theta$	Here E=120	120
Three-Phase (Delta)	$P = \sqrt{3}EI\cos\theta$	Here E=240	207.8*
Three-Phase (Y)	$P = \sqrt{3}EI\cos\theta$	Here E=207.8	120

*Volts to ground on lighting circuits is 120.

The two-phase (four-wire) system is so little used that no discussion is necessary.

PART 3—CIRCUIT PROTECTION

Fuses and all electrical circuit-breakers are similar in function to the safety valve on a boiler; and hence they should be seriously considered. They are all intended to open the circuit, thus stopping the flow of current, should the current exceed a predetermined or dangerous rate through these safety devices.

While the problem of circuit protection becomes at times quite involved, still there is much that can here be discussed to advantage. In the first place, the Natinal Electric Code is now almost universally accepted as the authority for the safe utilization of electricity in all except central station systems. Consequently, the engineer should obtain a copy of this useful and important publication.

Fuses and Circuit Breakers

Fuses are the cheapest and simplest of all protective devices. They consist of a piece of relatively high resistance alloy wire or tape, designed to melt, and thereby part, at the current at which the fuse is rated. The wire is enclosed in a suitable flame-proof case to prevent ignition of surrounding materials at the time the fuse flashes and melts. The use of fuses is now confined almost entirely to circuits the importance of which does not justify the more expensive and accurate devices. The type now approved, known as the "refillable type," permits the renewal of the fuse link, using the expensive part (the cartridge) over and over again.

For those applications in which the replacement of fuses is frequently necessary, thermal relays or air circuit breakers are to be recommended. Motor circuits fall in this classification. Thermal relays and circuit breakers can permit a greater than rated current pass for a short time, as during the starting period of a motor, and therefore are of especial advantage for this service. The current capacity as well as the voltage ratings of this class of protective devices are limited, and when greater limits are needed the oil circuit breaker must be used.

The oil used in circuit breakers must be especially selected for this service; and no other oil should ever be used. This precaution is essential for the reason that the oil must have high insulation value, high flash point, low carbon content, and wide temperature viscosity constant—all in order to quickly quench the arc that is formed with each opening of the contacts.

Relays

The overload operation of an oil circuit breaker is usually actuated by an auxiliary device known as a relay. Relays may be of several types: the instantaneous, the inverse time limit, and others. The modern relays are truly marvelous devices; however, the types needed by the water works plants are, in the main:

(1) *The Instantaneous Type*—dash-potted relays with direct mechanical trip. Here a coil which carries all or a definite part of the load current raises a solenoid when the current flow exceeds a predetermined value. The rising solenoid mechanically releases a trigger, which in turn permits the oil circuit breaker to open. An oil-filled dash-pot retards the solenoid movement. The dash-pot opening is adjustable, hence the time for opening with a given over-current can be selected as desired. The oil in the dash-pot should be inspected at intervals and replaced if dirt or sludge has accumulated. While rather crude, this device is sufficiently accurate for the protection of most small motor circuits.

(2) *The Air Bellows Type*—This type is not much used now. An air bellows, with an adjustable escape valve, is substituted for the oil dash-pot described above.

(3) *The Induction Type*—This relay is more expensive than those above mentioned, but its use is justified in the protection of all important cicuits.

With the induction relay, when the current exceeds the desired value, the torque on an aluminum disc, mounted on the same shaft with the relay contacts, causing the shaft to rotate. Such rotation causes the opening (some cases the closing) of the relay contacts, which in turn electrically energize the main tripping coil on the circuit breaker. The advantage of this type is that the time of opening the main circuit breaker can be determined to a fraction of a second; also, that the limits of control are so wide that these relays, with suitable current transformers, become almost universally applicable and highly accurate protective devices.

To repeat, too much care cannot be given the subject of circuit protection. Over-fusing (use of fuses with too great capacity) of circuits is dangerous and uneconomical. Noting a too frequent operation of the overload, protection of any appliance warrants prompt investigation. The source of the trouble should be remedied by correction, rather than following the easiest path of using too large circuit protection to overcome an annoying operating circumstance.

Grounding—Its Essentiality

It is no exaggeration to say that without adequate grounding, satisfactory electrical service would be virtually unknown. In addition, safety would be a word more than a reality. Even so, many groundings are so deficient in quality as to become actually a hazard instead of a safety effect. Many persons have been swindled into paying for a false sense of security when installing lightning rods having many ornamental glass balls but no grounds. Thereby the victim is actually inviting the lightning to strike the house but offering no protection by way of a cable or rod to conduct the electric discharge into the earth and there dissipate it.

Grounds should be carefully made. Use not less than No. 2 B&S gauge copper wire. Several grounds are preferable to a single ground in order to lessen the chances of broken connections. Use the water pipe system; the larger the pipe, the better. Do not use the gas, gasoline or oil pipe lines. Be sure the connection between the wire and pipe is electrically and mechanically as perfect as possible. If no pipe system is available, drive at least three 1¼-inch pipe, or equivalent copper rods, *well below the moisture line* in the earth. A good test is that the driven ground connection, when shorted, should blow a 30-ampere fuse at 120 volts.

Much discussion has recently been raised in the water works field as to the effects of attaching the electric circuit "neutral" wires to the water pipes. There is no question that the damage done to water systems by stray direct currents, as from street railways, has been indeed enormous. Here we have electrolysis at its worst, and the destruction of the metallic pipes at spots where the current leaves the pipes is rapid. This condition is inexcusable and should be prohibited everywhere.

However, in the alternating current system the damage is not so evident, and many doubt its *real* existence—or at least its seriousness. Also it is quite possible that were all connections between electrical and water systems removed, electrical service as we know it today would be a thing of the past. And even should such action force the electric companies to seek other means of obtaining the necessary protection now provided by these ground-

ing attachments, the water systems would be subject to the same distress now *debatedly* suffered. It would seem certain that more severe difficulties would be caused by the same currents finding their way to the water system in a then uncontrolled routing and dissipation which present practices have been designed to effect.

The necessity for grounding the electric circuits is to prevent dangerous high-potential voltages (through mistakes or accidental contact) from increasing the normally low-potential circuits to a dangerous loading. The wiring for lighting systems of buildings is designed for a maximum of 150 volts to ground. Let us assume that a street series circuit operating at 5,000 volts should fall across the service wires from the pole to your home. With no ground on the "neutral" of your secondary wiring, its potential would be raised from its normal low value to a maximum of 5,000 volts. Certainly something must happen; either a fire is started, or perhaps a member of your family may be killed. The effect of such danger has been observed when service thawing current reaches the house wiring. In these instances the "ground" has worked in reverse, but proves its safety value and the necessity of "breaking" the service line before electrical thawing is started. Now consider these same conditions to exist, except that now your "neutral" is properly grounded. When the high-potential circuit is now temporarily crossed with service, the high-potential currents are safely carried to ground, and no one in the home would realize the possible disaster that the ground connections have avoided.

When, What and Why Ground?

There is no doubt that a full study and discussion of the entire subject of grounding by the new functioning joint committee will prove well worth while. It is certainly to be hoped that there will result a greater care in the preparation and arrangement of ground connections between the electric and water systems, and that the volume of curent flow be intelligently regulated. We, the water utility interests, should not embarrass this effort by hasty demands to prohibit all grounding of water systems. As a matter of fact, we could not do so, even if thoughtless enough to demand such.

[Water works men have themselves found difficulty in effectively grounding pumping station motor circuits by any other method than an efficient connection to their own pressure mains leaving the station.—Ed.]

No wires used in lighting systems should have more than 150 volts to ground. The wires of power circuits, such as 220 or 440 volts, *should not be grounded.* All appliances, frames of motors, conduit, etc., in addition to the "neutrals" of lighting systems, should be carefully and effectively grounded. Inspect grounds frequently. The snuffing out of a life may be the penalty if you do not. Satisfactory operation is another, if secondary, reason for so doing.

PART 4—MOTORS

Alternating current motors are of two general types: the synchronous and induction. The main difference between these two types is that, while the synchronous motor can run only at a definite constant speed (synchronous speed), the induction motor must operate at a speed dependent upon the load applied, but never at synchronous speed. There are other important differences that, to better advantage, will be mentioned later.

Synchronous Type

At a given frequency the speed of a synchronous motor may be determined by the equation;

$$N = \frac{120f}{P} \quad \ldots\ldots\ldots (8)$$

in which N = revolutions of rotor per minute (RPM); f = frequency in cycles per second; P = number of poles.

Since the standard frequency is 60 cycles per second, equation 8 is generally expressed in the form:

$$N = \frac{7200}{P} \quad \ldots\ldots\ldots (9)$$

From this it is evident that the maximum speed for a 60 cycle motor is 7200/2 or 3600 RPM, and the speed, N, from equations 8 or 9 is known as the synchronous speed of the motor. This, for 60 cycle motors, is the constant 7200 divided by the number of poles; and, since the number of poles must be an even number, synchronous speeds become 3600, 1800, 1200, 900....RPM. One of the greatest limitations of the synchronous motor is that it cannot be built to operate at other than synchronous speeds, when oftentimes an intermediate speed is needed.

On the other hand, the fact that it runs at an exact speed is quite frequently its greatest asset. Electric clocks and timing devices depend upon this characteristic for their value and dependability as to accuracy. Pump drives, and mechanical devices of all types that require an exact and fixed speed, necessitate the use of the synchronous motor for this reason.

Another marked difference between the synchronous and induction motor is that the former requires salient magnetic poles, excited (magnetized) from a source of direct current; whereas, the induction motor has no such poles and requires no separate excitation. In fact, the standard squirrel-cage motor is well named, because its rotor is essentially nothing more than a circle of bars parallel to the shaft which are held in place and short-circuited by two metallic rings. Picture the revolving cage for the squirrel's exercise and you have it—thus, the name.

Unfavorable Characteristics

The necessity for this auxiliary direct current is indeed unfortunate, because direct current generators are difficult to maintain. Hence, greater skill and maintenance are required for synchronous than for induction motor operation. Then, too, the starting characteristics of the synchronous motor are rarely satisfactory. The starting torque (that is, the twist or pull) cannot approach that of the induction motor; frequently necessitating expensive and complicated methods of holding the load off the motor until it has reached full speed. Fortunately, centrifugal pumps may frequently be started under no-load without inconvenience, which renders this deficiency of the synchronous motor of no real importance.

Favorable Characteristics

On the favorable side of the ledger, the synchronous motor does possess the ability to operate with a "leading" power factor, contrasted to the rather decidedly "lagging" power factor of the standard induction motor. As has been stated previously, many power companies offer a lower rate to consumers whose requirements make permissible a desirable power factor. Where this is the case, the ability of the synchronous motor to operate at the "leading" power factor may have influence in the selection of the type of motor to be adopted.

From the above, it can be seen why, for water works and sewage treatment plants, the use of synchronous motors is frequently advised against. They are only to be considered when exact speed is essential or power costs may be lowered appreciably by the favorable power factor. Even then, the engineer will do well to be certain that savings in power bills will offset the increased operating difficulties that are certain to be realized in the use of synchronous motors.

Induction Type

The induction motor differs from the synchronous type in that it requires no separate excitation, and its ability to operate at a variable speed, as contrasted to the constant speed synchronous motor.

At no load an induction motor will run almost up to its synchronous speed. It should be understood that while the induction motor has no salient poles, the stator is wound to produce two, four or any even number of poles, just as is the stator of a synchronous motor; hence it has a synchronous speed of 3600, 1800, 900 RPM, just as does the synchronous type.

As the load on an induction motor is increased, the speed gradually lessens until at full rated load the speed is reduced from two to four per cent of its synchronous speed. Thus a given motor may have a synchronous speed of 1200 RPM, a no load speed of 1199 RPM and a full load speed of only 1170 RPM. If the load is further increased, the "slip" (as the loss of speed is called) will increase until a definite value is reached, at which point the motor will come to a stop. This load is known as the "pull-out" load.

Favorable Characteristics

Standard induction motors have very favorable starting characteristics, requiring relatively a small starting current and producing 200 or more per cent of full load torque. They are the most rugged and reliable of all motors. But while they will successfully operate under most adverse conditions, reasonable care should be taken to keep the air ducts and windings free from lint and dirt. The oil in the bearings must be flushed and changed at least once each year.

Smaller and specially designed induction motors require no starting device, and may be started by applying normal full voltage. Larger motors require reduced voltage for starting, which is

usually obtained from auto-transformers, called starting compensators. Two coils, each on an iron core, are connected open-delta across the three-phase lines; a 40, 50 or 60 per cent tap is taken to the motors for starting. After the motor has started and reached a constant speed, the compensator is disconnected and full voltage goes to the motor.

Variable Speed Motors

The wound-rotor induction motor, for operating at variable speeds, is not so rugged as is the standard squirrel-cage type. It is more expensive and also usually less efficient. A misunderstanding of the speed characteristics of these motors has caused no end of trouble. We may gain a clear conception of the speed variation of the wound rotor, induction type motor if we think in terms of "slip." As stated above, the standard squirrel-cage motor "slip" varies from virtually nothing at no load to about 3 per cent at full load. With the wound rotor, external resistance may be added to the rotor circuit, the effort of which is to *increase* the slip. Hence, this motor will run at essentially *constant* speed at no load, regardless of the amount of external resistance introduced in the rotor circuit. But, as the load is applied, and the greater is the external resistance, the more rapidly will the speed drop off.

Practically, this means that if we desire to drive a centrifugal pump at a variable speed, in order to vary the head and quantity delivered, we must first learn from the pump manufacturer both the speed and the horse-power required by the pump for each value of head-quantity desired. This data is then furnished the manufacturer of the motor who will design the external rotor resistances so that the various controller positions will connect the correct resistance to cause the speed to be that needed for the pump to operate under the desired condition.

Since power is a product of speed and torque, it should be remembered that less horse-power output can be obtained from a motor operating at a reduced speed than at its normal full speed. The reduction in motor output is approximately proportional to the reduction in speed. This fact should be considered at the time of purchase in order to be certain that the motor will not be excessively heated when operating at any of the reduced speeds. The same resistors that serve for speed control are also used for starting, hence no compensator is required as is the case for some of the standard squirrel-cage types.

Motor Ratings

The rating of most electrical apparatus such as motors, transformers, etc., is based upon the temperature rise that will occur when the device is operated continuously under normal full load and normal voltage conditions. Many manufacturers recommend a limit of fifty-five degrees centigrade rise, while other base their estimates upon a rise of only forty degrees. After all, this simply means that with a given motor rated at 100 HP, at 40 degree rise would be rated at 125 HP at 55 degree rise. All things considered, it seems to be the consensus of opinion, and dictate of wisdom, that all important motors in water works and sewage treatment plants should be purchased for a guaranteed rise, not to exceed forty degrees centigrade.

RAPID EMERGENCY METHOD OF THAWING HYDRANTS*

By E. E. JACOBSON

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One of the many worries of the water works man during the cold winter months is the problem of fire hydrant maintenance and their operation when the thermometer drops below freezing.

Proper inspection and drainage of fire hydrants will eliminate most of the trouble but hydrants only a few days after inspection have been found to contain water in the barrel. As the weather turns cold the water in the barrel becomes ice and the hydrant will not operate. No doubt every water works superintendent in states that have cold winters has experienced frozen fire hydrants.

The method used in Lexington, Ky., for a number of years as an emergency method of thawing ice from hydrant barrels is by pouring concentrated sulphuric acid into the hydrant barrel. During the Fall each piece of apparatus of the Lexington Fire Department is supplied with a quart bottle of sulphuric acid (66% commercial). When the acid is used the Lexington Water Company is notified and another bottle is sent to the fire station. In the Spring of the year these bottles are collected and fresh acid is issued each Fall.

When answering an alarm and a hydrant is found to be frozen, the acid is poured into the barrel through the nozzle and a slight pressure put on the stem operating wrench. As soon as the heat produced by the acid drills a hole through the ice cake the hydrant is opened, flushing out the acid with the first gush of water.

In frozen hydrants we have found that the ice forms first above the valve and in most cases it is doubtful if the acid reaches the valve because the stem turns and the water is turned on as soon as the ice melts around the stem.

The average time for thawing hydrants with acid is about three minutes although this would depend upon the thickness of ice in the barrel of the hydrant, and might vary considerably from the above time if very thick.

The advantages from this method of thawing hydrants comprise the ease of handling the thawing material on the fire trucks, the small space necessary on the trucks, simple to use, inexpensive, and the rapidity of results. Hydrants in which acid was used have been taken apart and no ill effects to the hydrant parts could be found.

The effectiveness in the use of sulphuric acid for this purpose can be determined by the following letter from the Chief of the Lexington Fire Department:

Mr. E. E. Jacobson, Chief Engineer — April 11, 1936.
Lexington Water Company,
Lexington, Kentucky.

Dear Mr. Jacobson:

Relative to our conversation this morning, I am furnishing you with all the information that I have in regards to the use of sulphuric acid in thawing fire hydrants during extreme cold weather.

In case a hydrant is found to be frozen, one of the caps of the hydrant is removed and a quart of acid is dumped into the barrel of the hydrant. The suction hose is then replaced on the hydrant, and in the majority of the cases the hydrant is thawed out by the time the suction is replaced, and the hydrant is turned on. The water and acid is allowed to flush out through the pumper or the hose, and we have found that little or no damage is caused by this action, due to the fact that the acid is neutralized by water to such a degree that it is harmless to the pumper or the hose.

In some instances the acid is a little slow about thawing the hydrant, but in these cases it is usually in certain parts of the city, where the surface water seeps in the barrel of the hydrant, causing the hydrant to have more water than usual in the barrel, but as soon as these hydrants are found, your company has had them filled with alcohol, thereby eliminating this trouble.

You will notice that we say that we replace the suction or the hose to the hydrant before we turn on the water. This is done to prevent acid burns to members of the department and the hose and apparatus that is near the hydrant. The first spurt of acid and water from the hydrant would be dangerous to any thing that it touched, but by replacing the cap, the acid is diluted with the water to a point where it is practically harmless to any thing it might touch.

It has required from two to eight minutes to thaw a hydrant with acid, where it usually requires about ten minutes to thaw out a hydrant with a regular thawing device, old style thawing device.

A test was made at fire department headquarters today. A fifty pound block of ice was used and one quart of sulphuric acid was poured into a hole in the ice. Ten minutes later a hole was burned in the ice eight inches deep, six inches wide and ten inches long. Of course, this was a little longer than it would have been in a hydrant, due to the fact that acid will follow the stem of the hydrant and penetrate into the ice faster than it did during the test. We have found the use of sulphuric acid for thawing hydrants to be most satisfactory.

C. J. Henry,
Chief, Lexington Fire Department.

*From Water Works and Sewerage, December, 1936.

WATER HAMMER

Its Study and Correction

By HENRY RYON
Senior Sanitary Engineer
N. Y. State Dept. of Public Works
Albany, N. Y.

IN ORDER to provide water for Clinton Prison at Dannemora, N. Y., it was found necessary to use Chazy Lake as a source of supply and to lift the water over Dannemora mountain to the prison reservoir. This required the installation of a pumping station and a force main about 4½ miles long with a rise of 530 feet. The pumping station and pipe line were put in operation late in 1932, and almost immediately trouble was experienced due to the failure of the lead joints in the pressure line. The cause of these failures was apparently the high pressures developed when the pumps were stopped, and studies were made to determine the best method of reducing these high pressures.

Installation

The pumping equipment consists of two electrically driven four-stage centrifugal pumps each having a capacity of 390 gallons per minute against a head of 619 feet. The pumps are set approximately at normal lake level. The suction line is of 10-inch cast iron pipe and is about 400 feet long. The discharge main is of 8-inch cast iron bell and spigot pipe, Class G to Class B, and is 23,720 feet long. The static head at the pumps is 530 feet, the equivalent of approximately 230 pounds per square inch. There is a standard swing check valve on the suction line and a similar check on the discharge line of each pump. A 6-inch spring loaded relief valve and an air chamber 8 inches by 96 inches in size were provided on the main discharge line near the pumps.

Line Pressure

In order to study the pressures in the discharge line a recording pressure gauge with a fast moving chart was connected to the line just beyond the relief valve. A typical pressure curve plotted by this gauge with one pump in operation and the relief valve and air chamber shut off is shown in Fig. 1.

The static pressure is 230 pounds per square inch. When one pump is started the pressure gradually rises to 310 pounds per square inch, the rise for each of the four steps of the starter showing distinctly, and then drops to the running pressure of 275 pounds per square inch. When the pump is stopped the pressure drops very quickly from 275 pounds per square inch to 90 pounds per square inch and then rises to 370 pounds per square inch. These subnormal and supernormal pressures continue at regular intervals, the variations above and below the static pressure becoming less and less as line friction gradually damps them out. The time of one complete cycle is 23.1 seconds, and since the water-hammer wave must travel four times the length of the pipe in one cycle, its velocity is at By comparison, the maximum velocity of flow in the pipe, with one pump in operathe high speed of 4,110 feet per second. tion, is only 2.49 feet per second.

It is, of course, the first super-normal pressure wave that causes most of the pressure wave cannot, however, be negdamage to the pipe line. The subnormal amount of air that can be retained in the lected for it very definitely limits the air chamber.

Water Hammer Waves

In order to explain the method evolved to control the water-hammer pressures, it is necessary to consider first the nature of a water-hammer wave. The magnitude and velocity of the wave depend upon the elasticity of the material composing the pipe wall, the velocity of the water in the pipe and the time in which that velocity or part of that velocity is extinguished. The yare independent of pressure in the pipe and flow velocity, except that part of the velocity that is extinguished. The water-hammer pressure or excess pressure is the variation above or below normal caused by the water-hammer wave. In this case (and in other cases where conditions are similar) the momentum ceases to deliver water almost instantly. The suction line being of the rotating parts of the pump and motor is so small in comparison with the load that when the switch is opened the pump short, no high pressure of any duration is developed in it that might force water through the pump. As a result the stopping of the pump has for all practical purposes the same effect as almost instantaneously closing a valve.

An Analysis

This effect can be examined best by considering the pipe line to be divided into a large number of very small sections of equal length.

When a valve at the inlet end of a pipe in which water is flowing is instantaneously closed, the velocity of the water in the section adjacent to the valve (in this case the pump), is immediately extinguished. This causes the water in this first section to expand, the pressure to fall and the pipe to contract. In other words, the kinetic energy of the moving water has been converted into potential energy. The water in the first section being at rest or static, the velocity of the water in the second section must necessarily cease. The water in the second section then expands, the pressure falls and the pipe contracts in the same manner as in the first section. This reduction in pressure in the second section in no way affects the pressure in the first section for the pressure in that section, excepting gravity and friction, is dependent entirely upon the destruction of the kinetic energy of the water in that section. And, the kinetic energy of the water

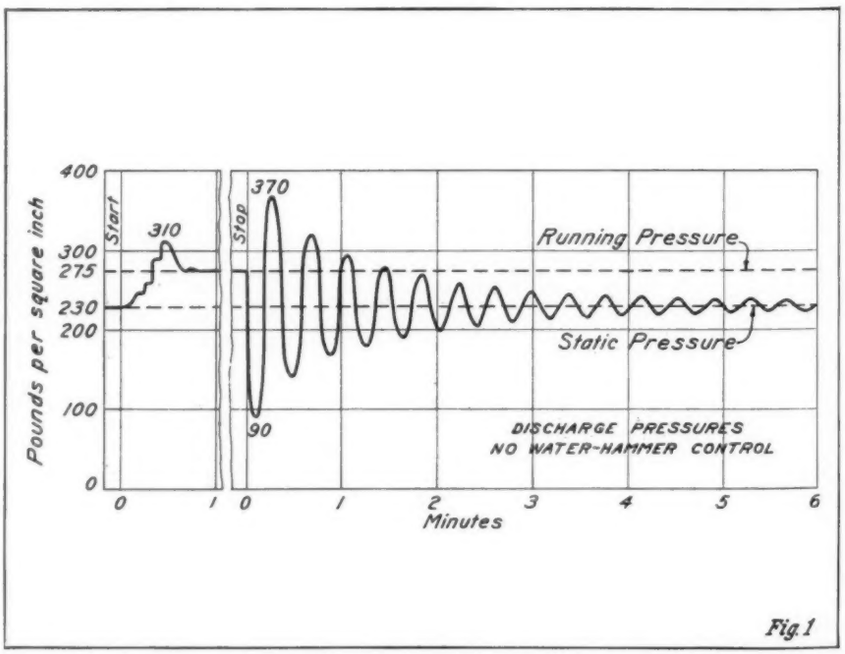


Fig. 1.—Typical Pressure Wave Graph
(One Pump Thrown Out; Relief Valve and Air Chamber Shut Off At the Time)

in the second section is exactly the same as that of the water in the first section and its destruction therefore produces exactly the same reduction of pressure. This process continues through the third, fourth and other sections of the pipe until all the water in the line has expanded, the entire pipe line contracted and the pressure throughout fallen by the same amount. The wave has traveled the length of the pipe once and the water is at rest.

This condition, however, is not stable. The water in the lower end of the pipe can-freeto contract. This it does immediately. not move, but the water inthe upper end is The water in the upper section contracts, the pressure rises and the pipe expands. As a result of this contraction of the water and the expansion of the pipe in the upper section, water flows into the pipe. Conditions in the upper section having thus changed, the second or adjacent section is free to move. The water in the second section then contracts, the pressure rises and the pipe expands. This draws more water into the pipe. In a like manner similar changes occur in the third, fourth and other sections until all the water in the line has again contracted, the entire pipe line expanded and the pressure throughout risen to the point (excepting friction at which it was before the valve was closed or the pump stopped. The wave has traveled the length of the pipe twice. The water is in motion and is flowing toward the pump with the same velocity, excepting for friction losses, at which it was flowing away from the pump before the pump was stopped.

This flow cannot continue, for while the wave has been traveling twice the length of the pipe, ample time has elapsed (11.5 seconds in this case) for the check valve at the pump to close tightly. The flow is therefore directed toward a closed valve and the velocity in the first section adjacent tothe check valve is instantly extinguished. The water in this section is compressed, the pressure rises and the pipe expands. The water in the first section being at rest, the water in the second section must necessarily come to rest with the same changes in condition as occurred in the first section. In a like manner, the water in the third, fourth and other sections come to rest successively until all the water in the pipe line is at rest and compressed, the pressure above normal and the pipe expanded for its entire length. The wave has traveled three times the length of the pipe and the water is once more at rest.

Again, however, the conditions are unstable. The water in the lower end of the pipe cannot move but that in the upper end is free to expand. This it does immediately. The water in the first section expands, the pressure falls and the pipe contracts causing water to flow out of the upper end. Conditions having changed in the upper or first section, the second section is free to move. The water in the second section then expands, the pressure falls and the pipe contracts causing a further flow of water out of the upper end of the pipe. Similar changes occur in the third, fourth and other sections of the pipe until all the water in the pipe has expanded, the entire pipe line contracted and the pressure (except for friction losses) fallen to the normal running pressure. The wave has traveled the length of the pipe four times. The water is moving away from the pump with the same velocity, excepting friction losses, that it was before the pump was stopped. In other words, one cycle has been completed, and conditions are the same as when the pump was running.

The cycle repeats itself until the friction gradually damps out the wave.

A diagram of the effect of this wave near the pump is shown in Fig. 2. The complete cycle is from A to G. The slope of the line from B to C is due to the fall in friction pressure as the wave passes up the pipe and the water gradually comes to rest.

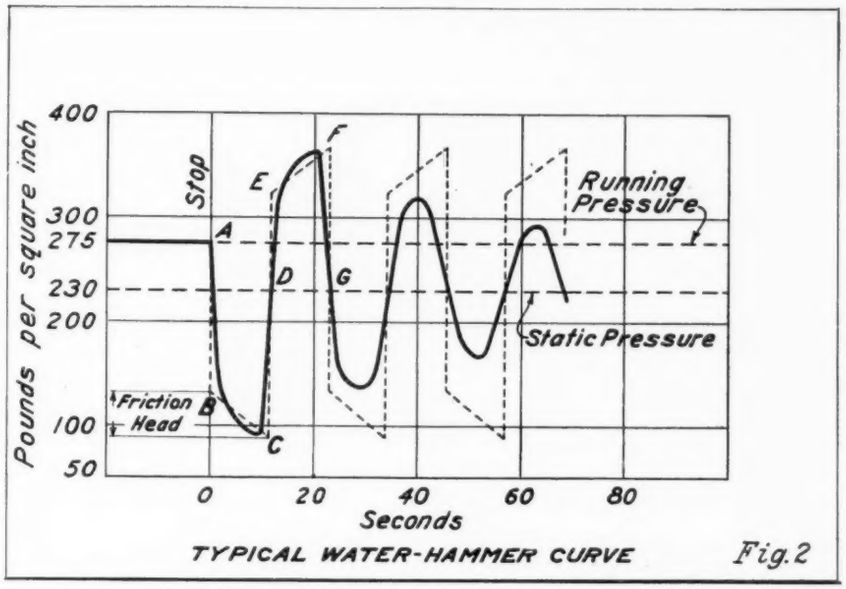


Fig. 2.—Graph of Wave Near the Pump (Explanation of Significance in Text)

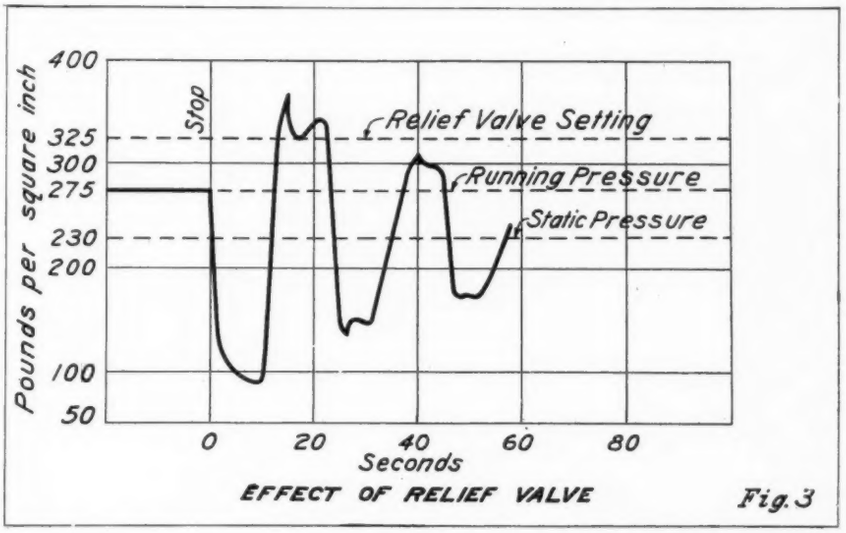


Fig. 3.—Graph Revealing Failure of Spring-Loaded Relief Valve to Relieve

The slope from E to F is due to the rise in friction pressure as the velocity away from the pipe is gradually regained.

A comparison of the velocities and pressure as observed and those computed by Joukovsky's formula (Jour. Am. Water Works Assoc., 1904, p. 341); (W. W. and S., April, 1938, p. 338) is interesting.

Joukovsky's formula for waterhammer, produced by instantaneous valve closure, is:

$$H = \frac{aV}{g}$$

$$a = \frac{12}{\sqrt{\frac{w}{g}\left(\frac{1}{K} + \frac{D}{Ee}\right)}}$$

H = Head due to water-hammer, ft.
a = Velocity of water-hammer water, f.p.s.
V = Velocity of water in pipe, f.p.s.
g = Acceleration of gravity.
w = Weight of one cubic foot of water.
K = Bulk modulus of elasticity of water, pounds per sq. in.
E = Modulus of elasticity of pipe material, pounds per sq. in.
D = Diameter of pipe, inches.
e = Thickness of pipe wall, inches.

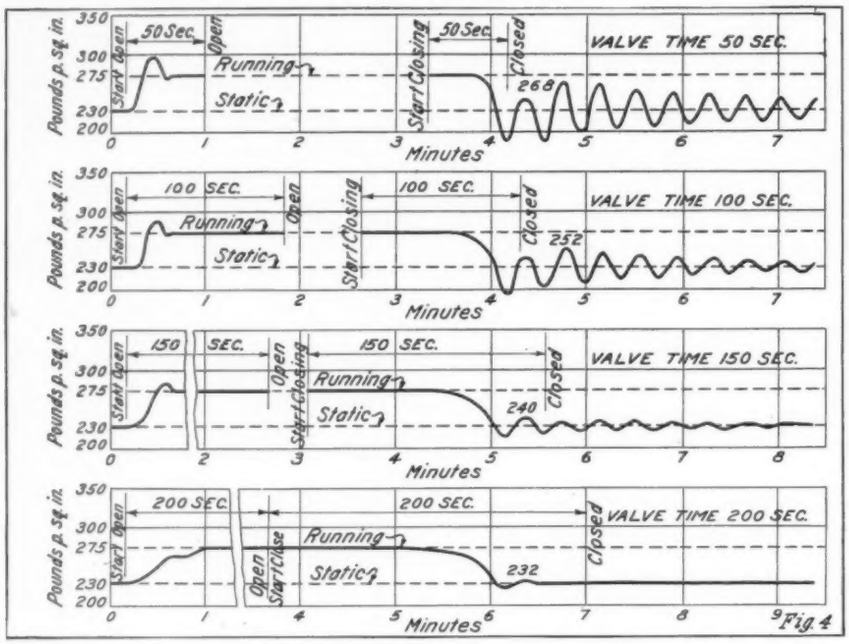


Fig. 4.—Graph Showing Results With a Cone Valve

The value of studying the effects of various closure times for surge suppression is effectively revealed in the four recorded graphs. A splendid testimonial as to the efficacy of properly controlled cone valves

The results are as follows:

Computed water-hammer head (negative)	326 ft.
Observed water-hammer head (negative)	322 ft.
Computed velocity of water-hammer valve	4220 f.p.s.
Observed velocity of water-hammer wave	4110 f.p.s.

If the pipe line had been shorter or the time of stopping longer so that the water-hammer wave set up by the first reduction in the discharge of the pump could have traveled to the end of the pipe and returned to the pump before the flow through the pump had stopped the returning supernormal wave would have interfered with the subnormal wave and the magnitude of the wave would have been reduced. So long as the returning wave does not reach the pump until its discharge is entirely stopped

$$t < \frac{aL}{2}$$

the result, for all practical purposes, is the same as that produced by an instantaneously closed valve. If it does return before the pump discharge has ceased, the interference of the waves must be considered. Except for this interference, the *water-hammer pressure is independent of the length of the pipe.* In the suction line which is only 400 feet long, the first wave returns in 0.2 of a second and interferes with the following waves, preventing, as stated before, the development of a pressure in the suction that might force water through the pump.

Relief Valves

When the Chazy Lake pumping station was built, a 4-inch spring loaded relief valve was installed on the 8-inch discharge line for the purpose of preventing any undue rise in pressure. This relief valve failed to produce the desired result. The effect of the relief valve on the water-hammer pressures shown in Fig. 3. The inertia of the moving parts in the valve apparently prevents it from opening rapidly enough to relieve the pressure and the head rises almost to the same value that it does without the valve in operation. When it finally does release the water the pressure falls to that for which the valve is set. The valve then closes and stops the flow of water through it. The stopping of this flow sets up another water-hammer wave and the pressure again rises.

In order to satisfactorily prevent high pressures by means of a relief valve, the valve must open *before* the first returning wave reaches the pump. That is, before the pressure reaches the point D in Fig. 2. At this time the water in the line is flowing toward the pump and the pressure is the normal static pressure. If the valve is open at this time the water will flow out of the valve with no material rise in pressure. The valve must close slowly or the stopping of the flow through the valve will set up another water-hammer wave with consequent high pressures. It is generally necessary to provide an auxiliary source of power if this method of preventing high pressures is used because the pressure in the lin eis subnormal at the time the valve must start to open and usually insufficient to operate any type of valve.

This arrangement is used effectively at the Dalecarlia Pumping Station, Washington, D. C. (Water Works and Sewerage, April, 1938, Page 353).* In this case the relief valve is of the hydraulically operated rotary plug type and the power for opening it is obtained from an independent water main near the station.

Air Chambers

The 8-inch by 96-inch air chamber provided on the discharge line from the pumps was found on test to be of absolutely no value in reducing the water-hammer pressures, and computations by the graphic method of Prof. Angus indicated that no reduction could be expected. An air chamber on the discharge line of a pump acts by supplying water to the line in gradually decreasing quantities after the pump has stopped, causing a gradual reduction in the velocity in the line instead of a sudden closed valve.

To prevent high pressures in a pipe line by closing a valve slowly instead of rapidly requires that the time of closing be considerable, and if an air chamber is to be effective it must supply water to the line for a considerable time. Not only must the air chamber be large enough to contain sufficient water to the air chamber be large enough to contain sufficient water to maintain this supply over the necessary period, but there must be sufficient air above the water to maintain the proper pressure on the water as the air expands. Air chambers, if they are to

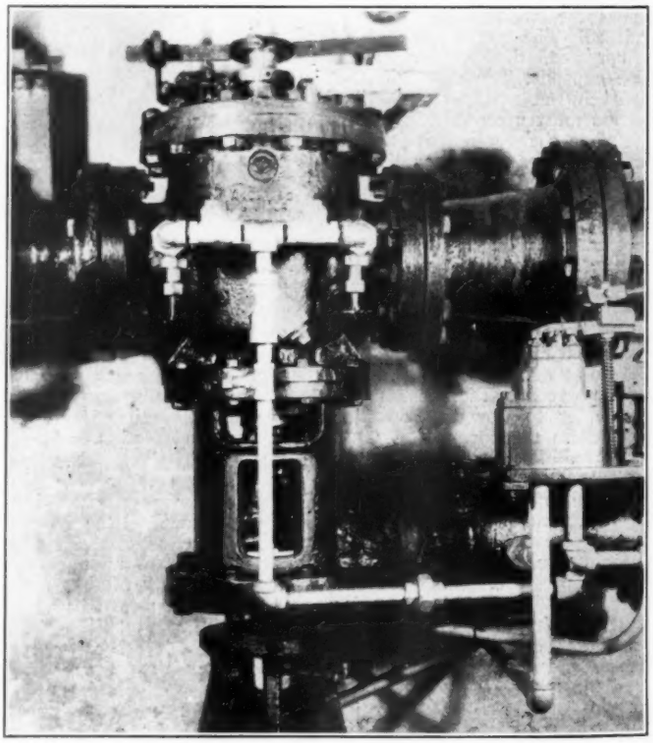


Fig. 4.—The Cone Valve

Which, with proper setting for closing time has solved the water-hammer problem

produce any measurable effect, must be far larger than those usually provided and often so large as to be impractical. Tests are now being conducted at the pumping station of another institution to determine the effects of air chambers of different sizes, but the results must await later publication.

Cone Valve in Discharge Solves the Problem

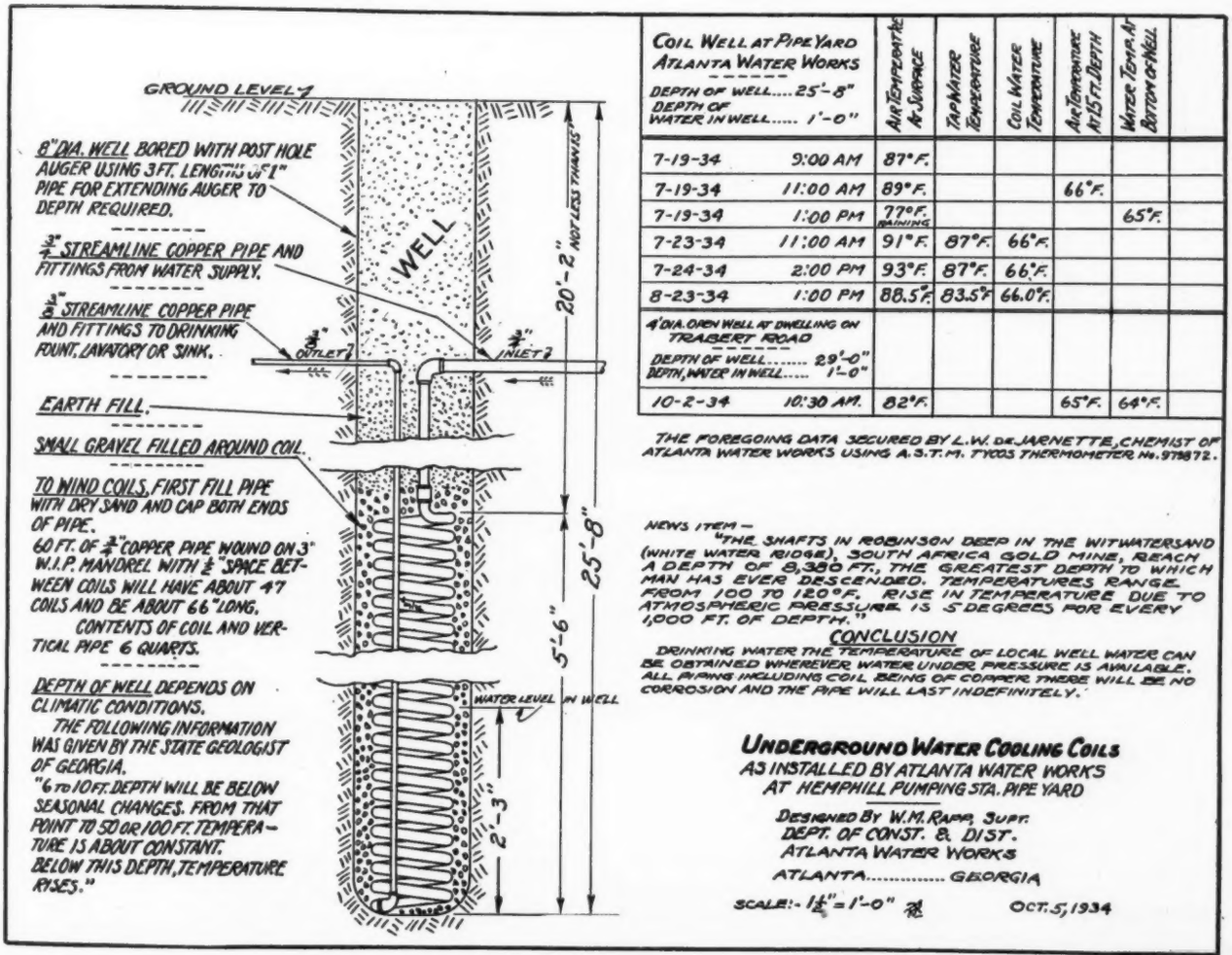
The method now used at the Chazy Lake pumping station to eliminate the high water-hammer pressures is to reduce slowly the velocity in the discharge line before the pump being used is stopped—this instead of allowing velocity to be suddenly extinguished by the stopping of the pump. This is accomplished by a 6-inch hydraulically operated cone valve located in the main 8-inch discharge line near the pumps (see picture). The cone valve is in closed position when the pump is started. Since a centrifugal pump requires the smallest amount of power when operating against a closed valve, the motor thus starts under minimum load. As soon as the pump reaches its normal speed the cone valve slowly opens, the time of opening being controlled by the setting of a needle valve on the water feed-line to the hydraulic cylinder operating the cone valve. When it is desired to stop the pump the cone valve is first closed slowly, gradually reducing the velocity in the discharge main. After the valve is entirely closed the pump is stopped in the ordinary manner. Electrical interlocks are provided so that the attendant cannot change the order of the operations.

Results

The results of this method of operation, for different timings of the valve, are shown in Fig. 4. This valve rises from its seat before turning and rescats itself after completing its rotary motion. The time given for opening and closing is the time taken for the valve to rotate through 90 degrees, and does not include the time taken for unseating and seating. There is some leakage past the plug when it is raised from its seat, and the stoppage of this leakage by the seating of the valve in some cases causes a slight secondary wave, as is noticeable in some of the curves. The destruction of the velocity in the pipe line is, of course, not proportional to the amount of rotation of the valve as is evident from the fact that the first 2/3 of the revolution produces no measurable effect on the pressure. The effective closing time is therefore only a fraction of the actual closing time. Setting the valve to close in 50 seconds keeps the water-hammer pressure below the running pressure. Further, increasing the time of closing reduces the water-hammer pressure until with a closing time of 200 seconds the excess pressure caused by water-hammer is scarcely noticeable.

At this pumping station only one pump should be operated at a time if economical results are to be obtained. Two pumps can, however, be operated at once with a consequent decrease in the delivery per pump and a decrease in efficiency. The water-hammer pressure produced by closing the cone valve with two pumps in operation is practically the same as that produced by closing the valve with one pump in operation, the time of closing being the same. The reason for this is that while the actual closing time is the same, the effective closing time, as indicated by the curves, is about twice as long with two pumps in operation.

This method of reducing water-hammer pressures does not protect the discharge line from water-hammer pressures due to power failure. Such protection can be afforded only by a properly timed relief valve operated by a separate source of power or by the use of an air chamber, both of which methods have been station, neither of these methods seemed practical because of the previously mentioned. In the case of the Chazy Lake pumping difficulty of securing a separate source of hydraulic or other power; and, the very large size of the air chamber required to produce even a small reduction in the excess pressure. At this station the water-hammer pressures do not rupture the pipe but do strain the lead joints, and the high pressures can be repeated several times before leaks occur. For these reasons, it was decided to protect the pipe line against the high pressures produced by the daily starting and stopping of the pumps, and to risk occasional high pressures due to power failures which may occur at very infrequent intervals.


GROUND LEVEL
8" DIA. WELL BORED WITH POST HOLE AUGER USING 3 FT. LENGTHS OF 1" PIPE FOR EXTENDING AUGER TO DEPTH REQUIRED.
¾" STREAMLINE COPPER PIPE AND FITTINGS FROM WATER SUPPLY.
¾" STREAMLINE COPPER PIPE AND FITTINGS TO DRINKING FOUNT, LAVATORY OR SINK.
EARTH FILL.
SMALL GRAVEL FILLED AROUND COIL.
TO WIND COILS, FIRST FILL PIPE WITH DRY SAND AND CAP BOTH ENDS OF PIPE.
60 FT. OF ¾" COPPER PIPE WOUND ON 3" W.I.P. MANDREL WITH ¾" SPACE BETWEEN COILS WILL HAVE ABOUT 47 COILS AND BE ABOUT 66" LONG.
CONTENTS OF COIL AND VERTICAL PIPE 6 QUARTS.
DEPTH OF WELL DEPENDS ON CLIMATIC CONDITIONS.
THE FOLLOWING INFORMATION WAS GIVEN BY THE STATE GEOLOGIST OF GEORGIA.
"6 TO 10 FT. DEPTH WILL BE BELOW SEASONAL CHANGES. FROM THAT POINT TO 50 OR 100 FT. TEMPERATURE IS ABOUT CONSTANT. BELOW THIS DEPTH, TEMPERATURE RISES."
WELL
OUTLET
INLET
20'-2" NOT LESS THAN 15'
25'-8"
5'-6"
2'-3"
WATER LEVEL IN WELL

COIL WELL AT PIPE YARD
ATLANTA WATER WORKS

DEPTH OF WELL..... 25'-8"
DEPTH OF WATER IN WELL..... 1'-0"

		Air Temperature At Surface	Tap Water Temperature	Coil Water Temperature	Air Temperature At 15 Ft. Depth	Water Temp. At Bottom of Well	
7-19-34	9:00 AM	87°F.					
7-19-34	11:00 AM	89°F.			66°F.		
7-19-34	1:00 PM	77°F. RAINING				65°F.	
7-23-34	11:00 AM	91°F.	87°F.	66°F.			
7-24-34	2:00 PM	93°F.	87°F.	66°F.			
8-23-34	1:00 PM	88.5°F.	83.5°F.	66.0°F.			
4" DIA. OPEN WELL AT DWELLING ON TRABERT ROAD DEPTH OF WELL..... 29'-0" DEPTH, WATER IN WELL..... 1'-0"							
10-2-34	10:30 AM.	82°F.			65°F.	64°F.	

THE FOREGOING DATA SECURED BY L.W. DE JARNETTE, CHEMIST OF ATLANTA WATER WORKS USING A.S.T.M. TYCOS THERMOMETER No. 979872.

NEWS ITEM—
"THE SHAFTS IN ROBINSON DEEP IN THE WITWATERSAND (WHITE WATER RIDGE), SOUTH AFRICA GOLD MINE, REACH A DEPTH OF 8,380 FT., THE GREATEST DEPTH TO WHICH MAN HAS EVER DESCENDED. TEMPERATURES RANGE FROM 100 TO 120°F. RISE IN TEMPERATURE DUE TO ATMOSPHERIC PRESSURE IS 5 DEGREES FOR EVERY 1,000 FT. OF DEPTH."

CONCLUSION

DRINKING WATER THE TEMPERATURE OF LOCAL WELL WATER CAN BE OBTAINED WHEREVER WATER UNDER PRESSURE IS AVAILABLE. ALL PIPING INCLUDING COIL BEING OF COPPER THERE WILL BE NO CORROSION AND THE PIPE WILL LAST INDEFINITELY.

UNDERGROUND WATER COOLING COILS
AS INSTALLED BY ATLANTA WATER WORKS
AT HEMPHILL PUMPING STA. PIPE YARD

DESIGNED BY W.M. RAPP, SUPT.
DEPT. OF CONST. & DIST.
ATLANTA WATER WORKS
ATLANTA..... GEORGIA

SCALE:- 1½" = 1'-0" OCT. 5, 1934

S-75

WATER WASTE SURVEYS

By A. D. STALKER*

Waste control, as a subject, can be divided very conveniently into two parts: First, that having to do with wastage which takes place inside houses and other buildings; and second, that concerned with wastage from the underground portion of the distribution system.

Meterage as a Remedy

By far the most effective method of dealing with the wastage that takes place inside buildings is by having services 100 per cent metered.

In cities or towns where none, or only a small percentage of the services are metered, the control of waste from defective plumbing fixtures is much more difficult. Systematic house-to-house inspection, regularly maintained by a permanent staff of inspectors, will prove a great aid in keeping this class of waste within reasonable bounds. These inspections must be frequently repeated, and to be effective must be supported by strong laws and good plumbing ordinances.

The public in general seems to think that the information contained in educational literature dealing with the importance of attending to small leaks and wastes should make a great impression—on somebody else. The value of this type of waste-control work is debatable. The writer's opinion is that the results obtained are not worth the trouble and expense of getting up and distributing the literature. *The only cure for waste due to carelessness is metering.*

The Pitometer

The second phase of waste reduction has to do with the location of leakage from the underground portion of the distribution system. To find the leaky parts of the underground system, a survey must be made to ascertain where the water goes after leaving the pumps, and what parts of the system receive excessive quantities. This can be accomplished by means of a pitometer.

The pitometer is an instrument that adapts the "Pitot" principle to the measurement of water. Two tubes enclosed within a metallic sheath are introduced into a water main through a 1-in. corporation cock. The tubes are set in such a position that one orifice faces directly up-stream and the other directly down-stream. They are connected by means of rubber tubing to the two legs of a glass U-tube containing a liquid of a specific gravity higher than water and which will not mix with it. The difference between the pressure on the downstream and on the up-stream orifices, which is the pressure due to velocity, causes a deflection of the liquid in the arms of the U-tube, and from this deflection the flow is calculated.

The prism photo recording pitometer makes a continuous photograph of the U-tube fluctuations upon a sheet of sensitized paper attached to a drum revolved by clock-work. The drum can be geared to complete a revolution in 12, 24 or 48 hours. From this photo record the flow through the main can be ascertained for any time during the gauging.

To measure accurately the flow through mains with the pitometer, the ratio of the mean velocity to the center velocity must be established, as the orifices of the instrument are set at the center. This ratio is called the "pipe coefficient" and is established by traversing the pipe. A pipe traverse is made by taking readings of the velocity at intervals across the pipe sufficiently close together to make a smooth curve when plotted. The pipe section is divided into rings of approximately the same area. The mean velocity of each ring in feet per second multiplied by the area of the ring in square feet, gives the ring volume in cubic feet per second. The mean velocity for the whole pipe section is the total of these ring volumes divided by the area of the pipe. The mean velocity divided by the center velocity is the pipe coefficient. On large mains it is desirable to traverse the pipe on two diameters 90 degrees apart and in the same plane. By using two rod meters, one can be left at the center of the pipe and the traversing done with the second, and readings taken when the center velocity is the same in each case. The pipe coefficient is the same for all velocities in the same pipe at any particular point, and it is upon the discovery of this principle that all pitometer gaugings are based.

*The late Prin. Asst. Water Works Engineer, Ottawa, Ont.

How Pitometer Survey Is Made

A pitometer survey should properly start at the pumping stations, and the discharge from the pump checked. When this has been done, I think it good practice to test all trunk or feeder mains before dividing the system into districts. These mains taken separately can be quickly done, and the distribution of water through that part of the system fed by them is interfered with for a much shorter time than would be the case if they were to form part of a district. Furthermore, trunk mains are usually so spaced as to form excellent district boundaries.

More accurate results can be obtained if the pitometer tap is placed on a small main feeding into the trunk main than would be the case if the tap were to be placed on the trunk main itself, as a flow that would cause scarcely any deflection of the liquid in the U-tube if the tap were on the large main, would cause a sufficiently great deflection to give an accurate measurement of the flow if the tap were on the smaller main. The tap may be placed in such a position as to serve as a gauging point both for the trunk main and one of the districts.

The next step is the dividing of the system into districts. This work must receive careful consideration. A district should be of a size that can be conveniently sub-divided in one night during the hours of minimum consumption, and the boundaries laid out with a view to causing as little interference as possible with the circulation through the balance of the system. The gauging point should be on a main of such a size that a velocity of about 4 ft. per sec. would supply the maximum normal demands of the district, without any allowance for leakage. This velocity will give a deflection of about 17 in. on the U-tube, using a liquid of 1.25 specific gravity. The maximum consumption would not be likely to cause a velocity great enough to blow the liquid out of the tube, and the minimum consumption would cause a fairly high deflection. When the district is first gauged, a velocity higher than the above will probably be recorded ,and a heavier liquid might have to be used. The idea behind choosing a main of this size is to ensure a deflection high enough to give an accurate measurement of the flow when all leaks have been stopped.

If the survey being made is an original one, a 48-hour record should be taken, including a Sunday if possible. Very careful records should be kept of all flows recorded and work done, and of any peculiar or unusual conditions that may be found to exist, as this information will, without doubt, be of great assistance in later surveys. Weather conditions and any circumstances which might affect the consumption of water should be noted.

When the flow is to be gauged, the district is cut off from the rest of the distribution system by closing all the valves on the boundaries, excepting on the pipe to which the instrument is connected. To make sure that the valves are holding properly, and that no water is getting in, either through them or through services that may be joined up inside buildings and connected to mains on both sides of a boundary, the main feeding the area enclosed should be closed and a hydrant at the highest point within the boundaries opened. If the hydrant is not off, the point at which the water gets into the district must be located, and the flow stopped. When it is assured that the whole supply passes through the main to which the instrument is connected, the district is ready for the taking of the record. Precautions should be taken to prevent street flushers drawing water from hydrants located within the district boundaries while the record is being taken. It is advisable also, to have a man with a valve key stationed at a fire hall either in or convenient to the enclosed area, so that valves could be opened with as little delay as possible in the event of a fire breaking out. If a fire occurs in a district while the flow is being recorded, the record will be ruined, and opening the boundary valves cannot make it any worse.

If the record taken indicates that an excessive amount of water passes the gauging point, and that the flow remains high during the hours in which very little water would be used, the district should be sub-divided. For subdivision purposes the mechanism revolving the drum of the pitometer is geared to complete a revolution of the drum in twelve hours. This will give a movement of an eighth of an inch in five minutes.

One method of sub-dividing is to divide the whole district into

sections as small as the spacing of the valves will permit, and then closing a section down for a short period (at least five minutes) and re-opening it, and repeating this operation with other sections, until all have been shut down. Another method is to start at the boundaries and work towards the instrument, gradually reducing the size of the district, and as the new boundary valves are closed, the old ones are opened. The method used will depend on the conditions that exist in the district. With either method, the time each shutdown is completed must be noted. It is important that all valve operations should be checked over before leaving the district, to make sure that no valves are left closed.

Locating the Leaks

When the subdivision record has been interpreted we will know the quantity of water each section of the district received. The sections that receive excessive quantities should be carefully gone over and the reason for the large flow ascertained. It is a good idea to have a plumbing inspector make a special examination of the fixtures in all buildings in these areas. If this inspection fails to account for the flow, it is assumed that the cause is underground leakage.

There are a number of methods usually employed to give the exact location of underground leakage. The one most generally used, and the one by which a great majority of leaks are found, is by sounding. There are a number of instruments on the market devised to help in picking up sounds, and those that I have used have proven of great assistance. The procedure is to sound all the valves, hydrants and services in the suspected area, and sometimes it is possible to get closer to the source by driving rods down to the main. It is remarkable what an experienced man can accomplish by sounding. In a great many cases he can not only tell where the leak is, but its nature—whether it is a blown joint, a split main, or a burst service pipe.

There are, however, a number of cases in which the sounds picked up are confusing. Where there are two or more leaks close enough together for the sounds to overlap, it is difficult to isolate the sound from one leak and trace it to its source. Leaks that discharge under water produce a sound that is often misleading. Then there is the abandoned service that has not been properly blanked at the main.

Other methods used in conjunction with sounding include testing the pressure at different points until the point of minimum pressure is located; noting the flow in sewers at the manholes; pounding the road surfaces to endeavor to locate cavities beneath the pavement, and searching in cellars and excavations for dampness.

If the above expedients fail to locate the leak, the primitive of digging is resorted to. It is quite probable that the first hole put down will not be in the right place, but from the conditions that exist at this point, a second hols is usually all that is necessary.

Water appearing any place should be looked on as a possible leak, if the reason for its appearance is not apparent.

Other Duties of Waste Reduction Department

In addition to the work outlined above, it is the duty of the department in charge of waste reduction to attend to all cases of flooding of cellars. The first thing to be done in these cases is to find whether or not the water department is responsible.

When serious breaks occur in the distribution system they usually give plenty of surface indication as to their locality. These are attended to by the trouble department. Bad breaks do occur without giving such indication, however, and these are followed up by the waste-reduction department. In such cases, the department first gets in touch with all the fire halls in the city, each of which has a pressure gauge installed, to find if possible an area in which the pressure has dropped. If no indication is given in this way, men are sent out to go over those parts of the system where it would be possible for the water from such a break to escape without surface indication.

The Pitometer Company

Water Distribution Engineers

48 CHURCH ST. — **NEW YORK, N. Y.**

Branch Offices
205 West Wacker Drive
Chicago, Ill.

THE X-RAY FOR PUBLIC WATER SYSTEMS

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75 State St., Albany, N. Y.
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OFFER THREE IMPORTANT SERVICES FOR WATER SUPPLY SYSTEMS

1. **WATER WASTE SURVEYS**
   locate hidden leaks and other sources of water waste, accounting for all the water that enters the distribution system. See Pitometer Bulletin No. 17.
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   ascertain which mains are overtaxed with resultant loss of pressure, and which mains are not doing all the work for which they were designed. See Pitometer Bulletin No. 18.
3. **DISTRIBUTION SYSTEM STUDIES**
   determine necessary extensions and replacements to meet present needs and future requirements over a twenty-five year period. See Bulletin No. 18.

Send for Bulletins Nos. 17 and 18 — Full information on request

COST OF MAKING A MAIN EXTENSION

A Handy Chart for Quick Reference in Answering Questions of Consumers, Councilmen, and Others

Compiled by
D. R. TAYLOR
Superintendent Water Department, Roanoke, Va.

The following excerpts are taken from an article by D. R. Taylor in the November, 1938, issue of "Water Works and Sewerage," in which he presents a very useful chart kept up-to-date and handy for the reasons here stated by the author.

"When a fellow meets you on the street and says, 'What will it cost me to put water mains in that development of mine in the Fairview Addition,' he might as well ask you 'how high is up,' as to ask you that question without any facts having been given in that one interrogation. You finally pry out of him the length of his proposed extension and then he doesn't know whether he wishes to lay 2,4 ,6 in. or what size of pipe; so, he says, 'what would you lay?' After you explain to him that it depends upon whether he wishes to give the barest domestic needs or install a real system that will meet the approval of the National Board of Underwriters, he decides he would like to have the comparative cost of both. Before he gets through he has asked you for detailed cost of every individual item, going into the laying of several sizes of mains—for instance, the cost of pipe, jointing, labor for laying, backfilling, etc. Most important is the pavement cutting and replacement and ground conditions, for a most nearly correct estimate. I have felt that it pays to know at least the majority of the answers, consequently the more of these questions I was asked about main extensions, the more anxious I was to be able to answer most of them out on the street; so, I sat down at home for a few nights and prepared a tabulated estimate of the cost of mains per foot. I checked these costs with the various actual costs that we have experienced over many years and finally arrived at the average figures, which I believe will answer at least most of the questions that you and I are asked about main extensions. The reader will most likely have to revise some of the figures, depending upon labor conditions, wage scale, overhead; and, of course, present-day prices on pipe. I have also found that this tabulation is a big help and time saver in making estimates on the big extensions that are made by our department in our regular expansion programs.

"Herewith a copy of our quick estimate sheet."

ESTIMATE OF COST OF MAINS PER FOOT

Labor at $0.38 per hour—Pit Cast Pipe at $60.00 per ton—De La vaud, per foot as indicated.

	Galvanized			Cast Iron—Pit Cast Pipe								
Size	1 in.	1½ in.	2 in.	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.	18 in.	20 in.
Trench—												
Width	18 in.	18 in.	18 in.	20 in.	20 in.	20 in.	22 in.	24 in.	26 in.	30 in.	34 in.	36 in.
Depth	31 in.	32 in.	32 in.	40 in.	48 in.	52 in.	54 in.	56 in.	58 in.	66 in.	70 in.	73 in.
Cover	30 in.	30 in.	30 in.	36 in.	40 in.	41 in.	41 in.	41 in.	41 in.	44 in.	46 in.	46 in.
LABOR & MATERIALS												
Trench and fill, cu. yd.	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90	$1.90	$1.95	$1.95	$2.00	$2.00	$2.00
Trench and fill, per ft.	0.27	0.28	0.28	0.39	0.47	0.51	0.58	0.66	0.76	1.02	1 22	1.35
Haul pipe	0.02	0.02	0.02	0.02	0 03	0.04	0.05	0.06	0.07	0.08	0.09	0.10
Lay pipe	0.02	0.02	0.02	0.03	0.06	0 09	0.12	0.15	0.18	0.24	0.27	0.30
Pipe (f o.b. siding)	0.10	0.17	0.22	0.28	0.63	0.97	1.40	1.87	2 38	3.75	4.53	5.22
Joint material	...	...	...	...	0.03	0.04	0.05	0 06	0.07	0.09	0.10	0.11
Sub-total	$0.41	$0.49	$0.54	$0.72	$1.22	$1.65	$2.20	$2.80	$3.46	$5.18	$6.21	$7.08
Overhead—15%	0.06	0.07	0.08	0.11	0.18	0.25	0.33	0.42	0.52	0.78	0.93	1.06
	1 in.	1½ in.	2 in.	2 in.	4 in.	6 in.	8 in.	10 in.	12 in.	16 in.	18 in.	20 in.
BASE COST	$0.47	$0 56	$0.62	$0.83	$1.40	$1.90	$2.53	$3.22	$3.98	$5.96	$7.14	$8.14
For DeLavaud Pipe—												
Pipe (per ft. f.o.b. siding)	...	...	...	...	0.56	0.82	1.17	1.57	2.02	3.09	3.72	4 34
BASE COST—(With labor and materials approximately the same as above)	...	...	...	...	$1 32	$1.73	$2.27	$2.86	$3.57	$5.20	$6.21	$7.13
ADD for Cement Lining	...	...	...	...	$0.03	$0.06	$0.10	$0 13	$0.17	$0.24	$0.27	$0.30
ADD for Cutting and Restoring Pavement												
2-in. Penetration	$0.20	$0.20	$0.20	0.22	0.22	0.22	0.23	0.25	0.27	0.31	0.34	0.36
8-in. Penetration	0.48	0.48	0.48	0.49	0.49	0.49	0 57	0.62	0.68	0.76	0.84	0.90
8-in. Concrete	0.70	0.70	0 70	0.75	0.75	0.75	0.80	0.87	0.95	1.05	1.15	1.20
Brick on Concrete Base	1.20	1.20	1.20	1.30	1.30	1.30	1.40	1.54	1.70	1.90	2.10	2.20

NOTE: All costs based on hand labor for trenching and backfilling, except compressed air used to cut pavement, drill hard rock and tamp backfill. BASE COSTS based on best conditions in non-congested sections.

ADD TO LABOR COSTS AS FOLLOWS:
10% for Intermediate Sections
20% for Congested Sections
110% for Shale
210% for Hard Rock and 6-in. Extra Depth of Trench for Clay Cushion.

For Fittings and Valves add 2% to 10% to BASE COSTS depending upon number and construction methods.

HYDRAULIC DEVELOPMENT CORPORATION

MANUFACTURERS OF HYDRO-TITE—A SELF-CAULKING COMPOUND FOR JOINTING CAST IRON WATER MAINS

MAIN SALES OFFICE:
50 CHURCH ST., NEW YORK, N. Y.

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A Symbol of Quality

PRODUCTS: Hydro-Tite; Tools and Equipment for use with Hydro-Tite. Braided Jute, Joint Runners, Wood-Burning Furnaces. Pouring Ladles, Pouring Pots, Yarning Irons and Hammers.

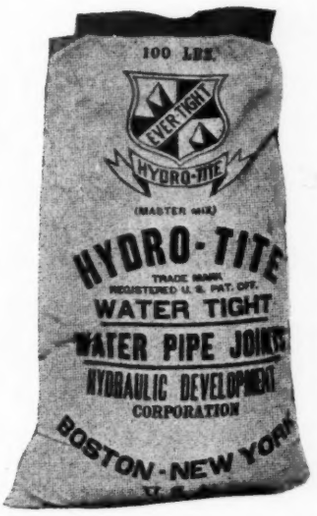
HYDRO-TITE is made in an up-to-date factory with modern machines and by efficient methods. It is made in powder form which insures greater uniformity besides having the advantage of melting quicker and being easier to handle.

For many years some of the best trained chemical scientists, besides the great laboratories of the Massachusetts Institute of Technology, have played a large part in making Hydro-Tite the leader in its field. Constant inspection, alert supervision and much research make the uniformity of Hydro-Tite what it is. This makes possible our continued use of the slogan—"more than 25 years without a failure".

HYDRO-TITE is a black powder scientifically compounded under skillful and careful supervision. It is composed entirely of selected inert minerals. When melted and allowed to cool, Hydro-Tite becomes a strong, tough, metallic mass. It has a high compressive strength of 6,000 lbs. per square inch and a tensile strength of over 650 lbs. per square inch. While Hydro-Tite has been used for a number of purposes, such as repairing leaks in reservoirs, breaks in castings, etc., its use is confined almost entirely to the making of cast-iron bell and spigot pipe joints.

SELF-CAULKING—Hydro-Tite melts over a small fire and nothing is added to make it become liquid. When poured into a joint it immediately solidifies upon contact with the metal and bonds to both the surfaces of the bell and the spigot for the entire depth of the joint. Hydro-Tite requires no caulking and after pouring a joint, water pressure may be immediately applied.

APPROVED BY—Hydro-Tite is approved and used by leading engineers, municipal water works, water companies, railroads, mines and industrial plants throughout this country and many others. It is also approved by the Associated Factory Mutual Insurance Companies and will be found listed on page 5, their "Rules for Laying Cast-Iron Pipe," issued June, 1929.



PACKED AND SHIPPED—Hydro-Tite is packed and shipped in 100-lb. heavy burlap bags. While age and dampness do not affect the quality of Hydro-Tite, it will handle much easier if dry. Each bag contains a specially treated moisture-proof liner which keeps the Hydro-Tite dry even though stored in a damp place or transported in the rain.

SELF-SEALING—Hydro-Tite, under normal conditions, will make prefectly tight joints when pressure is first applied. While it is the nature of jointing compounds to leak at first, Hydro-Tite joints are almost always bone-dry. Should a Hydro-Tite joint seep or leak a little at first, if left alone it will soon seal itself and become absolutely tight. One of the major claims made for Hydro-Tite is "less leakage from the start and quicker sealing qualities in case of small leakage". Even large running leaks, which may have been caused from pouring Hydro-Tite when it was too hot, will seal themselves and become tight in a day or two. Seepage rarely continues more than a few hours and often seals up in less than an hour.

The use of Hydro-Tite is standard practice in many water companies and water works throughout every section of this country and Canada. It is also used in various Central and South American countries and frequent shipments are made to points throughout the civilized world.

It is a significant fact that a good proportion of the private water companies in the United States and Canada are confirmed Hydro-Tite users. Many discriminating water works engineers, seeking the best by testing various jointing materials, select Hydro-Tite for joints on cast-iron pipe lines of all sizes.

We will be glad to refer you to some officials of large and small water systems located near you who are using Hydro-Tite. Your inquiry will receive prompt attention and will incur no obligation.

OVER 25 YEARS IN SERVICE WITHOUT A SINGLE FAILURE

REGULATING WATER PIPING WITHIN BUILDINGS*

By STEPHEN H. TAYLOR

Superintendent, Water Department, New Bedford, Mass.

It is the opinion of the writer that sufficient attention has not been given in the past by water works officials to water piping and fixtures inside of the taker's premises.

Until last year, we in New Bedford have felt that when we assured ourselves that the service pipe to and including the meter were of proper material and properly installed our responsibility and jurisdiction ended; and, what was installed inside of that point was wholly the affair of the owner and his plumber. I think it is safe to say that most water works officials in this country have taken the same attitude.

In consequence, we find in many cases that faulty workmanship has been a result and inferior materials have been installed. In addition, sanitary fixtures are often of a design and so installed as to unwittingly introduce a danger to health through pollution of the water supply within buildings by siphonage or gravity backflow of polluted water from bowls and other fixtures to the water supply piping. Speculative and boom building has resulted in many buildings being piped with cheap materials and fixtures, installed frequently by incompetent workmen.

It is a well known fact that the surface water supply of New Bedford is rather active and quickly fills wrought iron and steel pipes with rust and tubercles. This condition exists also in many other communities. In spite of such knowledge, many buildings have been piped with this type of material, with the result that after comparatively few years, water cannot be drawn through more than one fixture at a time and that one delivers only a weak supply. Services installed by the Water Department in New Bedford are of lead, in sizes up to 1 inch; and, copper or cast iron is employed for the larger sizes. In most cases we have installed the service up to the meter, which is usually located in the cellar of the building.

When complaints of poor flow come to us we clear the tap and service line, if necessary, and prove that the supply is ample up to the meter and that the trouble is caused by rust choking of the steel piping inside the building. This means many unnecessary visits and explanations; which takes considerable time of our employes. When the owner finds that his only remedy for the trouble is to repipe the entire building, to say that he is somewhat disturbed, is stating the case mildly.

We have also found that modern fixtures frequently of such a design that polluted water from them can flow back into the water supply pipes either by gravity or siphoning in case the pressure is reduced by heavy draught on the lower floor of buildings, or wherever the water is shut off in either the building or in the street.

Water Board Drafts Regulations

In an effort to improve these conditions the Water Board adopted a set of rules and regulations, which became effective June 1, 1935, governing the installation of house piping, which we feel will benefit the water department—but, more especially the public.

The city ordinances places the supervision of hot water tanks and water heaters under the jurisdiction of the City Board of Health. That department works in cooperation with our department regarding this equipment and has established rules which require that such equipment be installed in a manner which will be safe and prevent forcing hot water back to damage meters.

The new regulations follow.

[Note.—At this point the author outlined those parts of the regulations which embrace the principal requirements pertaining to "Inside Piping and Fixtures." Believing that our readers may prefer to have before them the completed set of regulations, these are reproduced below (in full) just as they appear in the neat little brown booklet (3¾ x 6 in.) which is distributed by the New Bedford Water Department.—Editor.]

New Bedford Water Board Regulations Governing Water Service Supply Piping and Fixtures† June 1, 1935

(See separate pamphlet for sprinkler piping regulations)

Section I. Every water-taker shall pay the established rates for water supplied within the time and at the place specified upon bills rendered; shall at his own expense, keep the service pipes within his premises in good order and repair and protected from the frost; shall not allow the water to run to waste; shall not make any change in the service pipe between city main and meter, unless sanctioned so to do by the superintendent; shall not conceal the purpose for which water is used; shall allow the superintendent, registrar and persons authorized by them, or by the board to enter the premises supplied with water to examine the pipes and fixtures and ascertain the quantity of water used and manner of use, and shall indemnify the city for all damages it may sustain or be required to pay, in consequence of any injury resulting from any violation of these regulations by the water taker.

Section II. All applications for service supplies must be made by the owner of property at the office of the registrar in the form prescribed, stating the various uses to which the water is to be applied.

Section III. SERVICE FROM STREET—In every case the installation of the service pipe from the street main to the end of pipe where taker's stop with waste is installed by the plumber shall be made by the New Bedford Water Department and the charge to the owner shall be as specified in regulation adopted by the Water Board February 6, 1924, viz.:

For installing one service to each property from the main pipe to street line as follows:

For ⅝ in. service	$31.00
For ¾ in. service	32.00
For 1 in. service	39.00

In cases where permanent pavement is disturbed, the owner is also required to pay for replacing the same.

For secondary services, temporary services or for services larger than one inch in size, the entire cost of installation, including cost of re-surfacing permanent street pavement.

For all services on private property, the owner shall pay the entire cost of such work.

Section IV. Each service shall be provided with a satisfactory stop and waste cock with coupling (this stop shall be round way and of the same size as the service pipe) to be located always just within the basement wall, at the point where the service pipe enters, and the pipes within the building must be so arranged that the water can be drawn from them whenever there is danger of freezing. The department will not be liable for any damage resulting from a failure to observe this important rule.

Section V. No water-taker shall be entitled to any damages nor will any portion of a payment be refunded for any sudden stoppage of the city supply occasioned by an accident or otherwise, nor for any stoppage for the purpose of making extensions, alterations or repairs. In such an event the water-takers must guard themselves against the collapse of boilers and other injuries liable to result from stoppage of the water supply.

Section VI. No cross connections between the City supply and any other supply which is not approved as potable by the State Dept. of Public Health shall be permitted except those which are properly protected by double check valves of an approved type. Said check valves shall be approved by the Water Board and shall be regularly inspected at the expense of the owner of the property by a representative of the Water Department at such intervals as the Water Board shall determine.

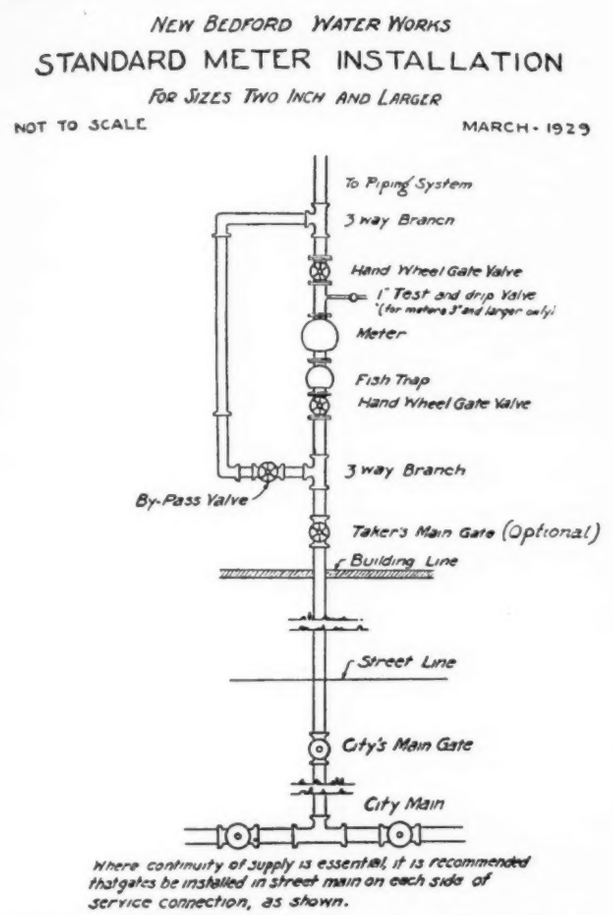
Section VII. METER REGULATIONS.

a. One meter of standard type and of same size as the supply pipe must be installed upon each service connection. It may be located between the curb stop and building or within building. If within building, it must be placed at a point adjacent to shut off, where pipe enters through foundation wall. If outside the building, it shall be installed in a satisfactory box or pit not less than 3 ft. x 4 ft. x 4 ft. deep. All meters 2 inches or larger shall be equipped with a by-pass capable of supplying the premises when the meter is removed for repairs or test. This by-pass valve to be kept sealed shut except when meter is out. (See Sketch.)

b. In all cases where one service connection supplies two or more separate consumers, or a block occupied by divers parties, only one meter will be used and the water rent as registered by said meter shall be charged to and payable by the owner of said premises or building. If additional meters are desired to ascertain sub-division or such supplies, they will be

*From Water Works and Sewerage.

†Regulations pertaining to inside piping and fixtures begin with Section VIII.


NEW BEDFORD WATER WORKS
STANDARD METER INSTALLATION
FOR SIZES TWO INCH AND LARGER
NOT TO SCALE
MARCH - 1929
To Piping System
3 way Branch
Hand Wheel Gate Valve
1" Test and drip Valve
(for meters 3" and larger only)
Meter
Fish Trap
Hand Wheel Gate Valve
3 way Branch
By-Pass Valve
Taker's Main Gate (Optional)
Building Line
Street Line
City's Main Gate
City Main
Where continuity of supply is essential, it is recommended that gates be installed in street main on each side of service connection, as shown.

Standard Meter Installation, New Bedford Water Works.

furnished at the expense of the applicant, who must assume all responsibility of reading and maintaining same.

c. Owners of property will be given option of either purchasing a meter outright and paying for its installation, or of having city furnish and install same and paying an annual rental therefor.

d. The property owner must keep the meter within his premises easily accessible for reading at all times. The city will include all repairs due to ordinary wear in its rental charge, but in all such cases, the owner will be held responsible for proper protection of the meter from all damage which may occur due to freezing or from hot water backing from overheated house boilers or other causes. Property owners will be assessed the cost of repairs of every nature necessary to properly maintain the meter owned by them. In case payment of such charges is not made upon demand, the water will be shut off from the premises supplied, and will not be renewed until after such charges, including the additional sum of one dollar, to cover expenses of shutting off and letting on the water, shall have been paid.

e. The owner of property shall pay at the established meter rate for amount registered, whether used or wasted. The water department will not assume any responsibility for use of water within metered premises.

f. Should a meter fail to register for any cause, the quantity shall be determined and the charge made based on average amount registered by meter when in order.

g. After a meter has been installed, it will not be removed for purpose of rating the premises supplied on any other basis of water charged.

h. No meter shall be discontinued from the pipe, moved or disturbed, without permission from the water registrar, who will send a properly authorized person to attend to any change needed.

i. If a house becomes unoccupied, the owner or agent may have the water shut off and the meter removed during the period of non-occupancy by making a request therefor to the water department, and paying one dollar to cover expenses.

Section VIII. PLANS TO BE APPROVED—Plans of proposed new installations, extensions or alteration of existing systems, showing proposed sizes and materials, must be filed with the Water Board, and approved by said Board or its designated representative before starting work.

Section IX. INSIDE PIPING—All inside installations shall be made under the direction of a registered Master Plumber, except in manufacturing plants or other plants where competent pipers are regularly employed. Connections to supply water heaters, hot water storage tanks, heating and ventilating apparatus, cooling systems and power plant equipment and apparatus may be made by competent employes of persons regularly engaged in the business of installing such apparatus, subject to the inspection and approval of the Water Board. Each holder of a Master Plumber's Certificate of License shall register his name and business address with the Water Board on or before the first day of May in each year. Notice of any change in the place of business shall be given immediately to said Water Board.

Section X. INSPECTION AND TEST—On completion of the installation it shall be inspected and approved by the designated inspector of the Water Board before the water supply will be turned on to the premises. It shall be tested in the presence of the inspector at city water pressure.

Section XI. KIND OF PIPE—All water supply pipes and fittings, shall be of lead, brass, copper or other non-ferrous metal or composition, except in the case of pipes four inches or more in diameter, in which case, cast iron pipe properly coated and lined with material approved by the Water Board may be used.

In order that piping shall be sufficiently strong to withstand City pressure with a reasonable allowance for corrosion all pipes must comply with the following minimum specifications.

LEAD PIPE:

All lead pipe for water service shall be made from soft virgin pig lead without any admixture of scrap lead or any other material and shall weigh not less than

For	½ in. pipes	3	pounds per foot
For	⅝ in. pipes	3½	pounds per foot
For	¾ in. pipes	4½	pounds per foot
For	1 in. pipes	6	pounds per foot
For	1¼ in. pipes	7¾	pounds per foot
For	1½ in. pipes	11¼	pounds per foot
For	2 in. pipes	19½	pounds per foot

BRASS PIPE:

All brass pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Brass Pipe, Standard Sizes" Serial Designation B43-23, with the exception of Paragraph 4 thereof. In place of the said Paragraph 4, the brass shall conform to the following requirements as to chemical composition:

Copper, minimum	59.00%
Lead, maximum	0.50%
Iron, maximum	0.07%
Zinc, or Zinc and Tin	Remainder

This change admits use of so-called "Admiralty" and "Red" brasses.

COPPER PIPE:

All copper pipe used for water supply piping shall conform with the Standard Specifications of the American Society for Testing Materials for "Copper Pipe, Standard Sizes," Serial Designation B42-23.

COPPER TUBING:

All copper service tubing used for underground piping shall conform with the Standard Specifications of the American Society for Testing Materials for Copper Tubing, Government Type K, Serial Designation B88-33. For interior piping copper tubing, Government Type L, is allowable.

Fittings for use with brass or copper pipes shall be of material and strength corresponding with the pipe used. All installations shall be made in a thorough and workmanlike manner satisfactory to the New Bedford Water Board.

Pipes which are to be concealed in partitions or otherwise shall be tested as specified in Section X before being concealed.

No pipes which have previously been used for other purposes shall be used for distributing water.

Section XII. PROTECTION—All concealed water pipes, storage tanks, flushing cisterns, and all exposed pipes or tanks subject to freezing temperatures shall be efficiently protected against freezing.

Section XIII. DISTRIBUTION—The water supply shall be distributed through a piping system entirely independent of any piping system conveying another water supply.

Section XIV. WATER SERVICE—The water service pipe of any building shall be of sufficient size to permit a continuous ample flow of water to all fixtures on all floors at a given time.

Section XV. SUPPLY TO FIXTURES—All plumbing fixtures shall be provided with a sufficient supply of water for flushing to keep them in a sanitary condition and shall be ad-

justed to prevent waste of water. The water from water closet and urinal flush tanks shall be used for no other purpose.

The bottom of flush tanks for water closets or urinals shall be above the overflow level of the fixture when drain is obstructed.

All flushometer valves for water closets shall be equipped with a vacuum breaker of a type approved by the Water Board.

The supply pipe for each tenement or bathroom shall be not less than ½" inside diameter and connect to the main supply pipe, which shall be not less than the size of the main service. The main service shall be carried full size to the point where the last branch is taken off in the basement.

Accessible shutoffs with waste shall be provided in the basement which shall separately control the water supply for each tenement and for each hot water tank.

Section XVI. SIZE OF PIPES—The minimum size of water-service pipes from main to the dwelling shall be five-eighths inch, and to fixtures as follows:

Sill Cocks	½ in.
Hot Water Boilers	½ in.
Laundry Traps	½ in.
Sinks	½ in.
Lavoratories	⅜ in.
Bath Tubs	½ in.
Water Closet Tanks	⅜ in.
Flushometer Valves for Water Closets	1 in.
Flushometer Valves for Urinals	½ in.

[Note: A copy of the application form, for Water Department approval of piping and fixture installations, may probably be had upon request to the author of this article—*Editor.*]

Some Results

It is interesting to note that in spite of the fact that no new building has been going on in New Bedford during the 8½ months since these rules became effective about 700 permits for alterations and replacements have been issued.

Two outstanding cases of potential pollution from back syphoning have recently come to the attention of our inspector. One was in a large High School; the other in a department store of importance. These cases and many others show the need of constant vigilance on the part of someone, and we in New Bedford have decided that the Water Department should assume this responsibility as there is a possibility that pollution from such sources may even get back into our mains by siphonage or gravity when it becomes necessary to shut off the street mains.

The inspection has been placed in the hands of a Master Plumber of long experience who has the respect and confidence of other master plumbers. He is a full time employee of the Water Board and has the complete cooperation of the plumbing inspector of the City Board of Health.

The new regulations have been in effect since June 1st, 1935, and the results have been very satisfactory. The master plumbers cooperate very well with us as it protects them against unfair competition of unlicensed men and inferior materials. The public gains by being assured of proper supply and approved water fixtures. The department gains by being relieved of many complaints which come about as the result of improper materials or workmanship.

As far as the writer knows, very few communities have made rules regulating water service piping and fixtures inside of buildings. No matter how complete the main distribution system and service connection may be, the consumer will not get the supply he is entitled to at his fixtures or the protection against pollution within his own property unless someone sees to it that proper interior piping and fixtures are installed in an approved manner.

Our City Solicitor has ruled that the supervision of the entire water supply (except water heaters and hot water tanks), up to and including proper fixtures, is within the jurisdiction of the Water Department.

Inclined Diagonal Pipe Runs—Calculating Pipe Lengths

By CHARLES FRICK

Darby, Pa.

Water works men may find the following formulas interesting and helpful in figuring lengths of pipe and tie rods on inclined diagonal runs.

The formulas are also useful in finding the approximate angle of fitting, theta (Θ), required (when bell and spigot pipe and fittings are used) when the dimensions in three planes have been decided upon.

The evolution of the formulas (see illustration) are also given in case the principle of revolution to a vertical plane may have further advantages in similar problems.

The subtraction of the center to end of spigot and center to back of bell taken from D gives the true length of pipe required.

Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

A.—When measurements in three planes are known, then

$$D = \sqrt{A^2 + B^2 + C^2} \qquad \text{Formula I}$$

$$L\ (\Theta)^{-\tan} = \frac{\sqrt{A^2 + B^2}}{C} \qquad \text{Formula II}$$

Example: Let A = 5′6″, B = 3′0″, C = 14′9″
Find (Θ) and length of pipe required on 8″ line.

$$D = \sqrt{(5.5)^2 + (3)^2 + (14.75)^2}$$
$$= \sqrt{30.25 + 9 + 217.56} = 16.025' \text{ say } 16'0''$$

$$L\ (\Theta)^{-\tan} = \frac{\sqrt{(5.5)^2 + (3)^2}}{14.75} = \frac{\sqrt{30.25 + 9}}{14.75}$$
$$= \frac{\sqrt{39.25}}{14.75} = \frac{6.265}{14.75} = 0.42474$$

L (Θ) = 23° + and a one-sixteenth curve may be used.
Length of pipe = D — (C to E of S. + C to B of B.)
= 16′0″ — (2′1″+) = 13′11″—

B.—When measurements in two planes are known and angle of fitting (Θ) decided upon, then

$$D = \sqrt{A^2 + B^2} \times \text{Csc } (\Theta) \qquad \text{Formula III}$$

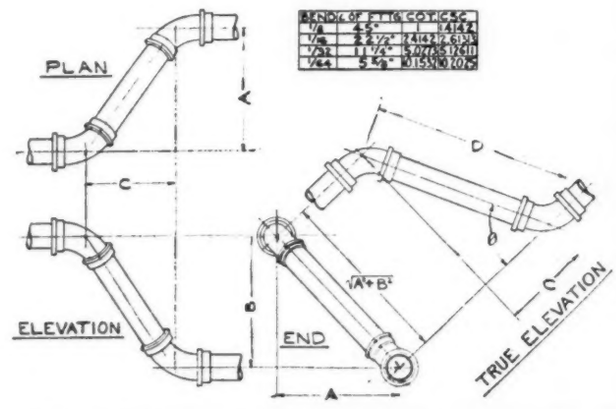
$$C = \sqrt{A^2 + B^2} \times \text{Cot } (\Theta) \qquad \text{Formula IV}$$

Example: Let A = 8′0″, B = 9′6″, (Θ) = 45°
Find—C and length of pipe required on 12″ line.

$$D = \sqrt{(8)^2 + (9.5)^2} \times \text{Csc } 45°$$
$$= \sqrt{64 + 90.25} \times 1.4142$$
$$= 17.56' = 17'6\tfrac{3}{4}''$$

Length of pipe = D — (C to E of S. + C to B of B.)
= 17′6¾″ — (2′1⅞″) = 15′4⅞″

$$C = \sqrt{(8)^2 + (9.5)^2} \times \text{Cot } 45°$$
$$= \sqrt{64 = 90.25} \times 1$$
$$= 12.42 \times 1 = 12.42' = 12'5''$$



Sketch Explanatory of Formulas for Lengths of Pipe for Diagonal Runs and Angle of Fittings

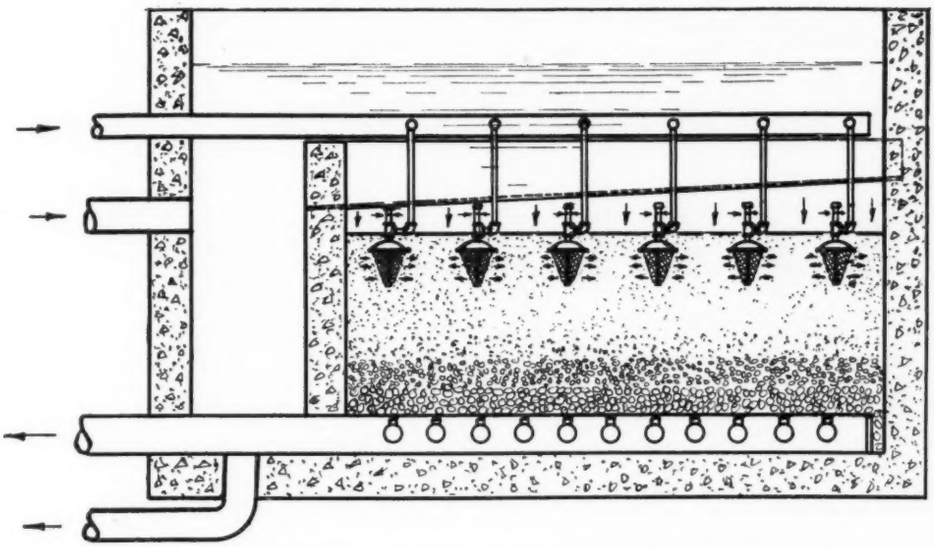
GRAVER TANK & MFG. CO., INC.

NEW YORK
CATASAUQUA, PA.

EAST CHICAGO, INDIANA

CHICAGO
TULSA

WATER TREATING SYSTEMS



Cross section showing application of Graver Sub-surface Filtration System

GRAVER SUB-SURFACE FILTRATION SYSTEM

If your problem is one of insufficient filter area for the amount of water demanded from your filtration plant, it will be to your advantage to investigate the Graver Sub-surface Filtration System. This system increases the amount of filtered water delivered from any given size filter by as much as 50% and does so without sacrifice in clarity of filtered water.

When installing new equipment, a smaller filter will serve your needs, through the use of a Graver Sub-surface Filtration System.

The advantages of this modern system are: Gives 50% more filter area, requires less backwash water, avoids frequent replacement of filter sand, more efficient washing of filter bed, avoids mud ball formation, and prevents upsetting of filter bed.

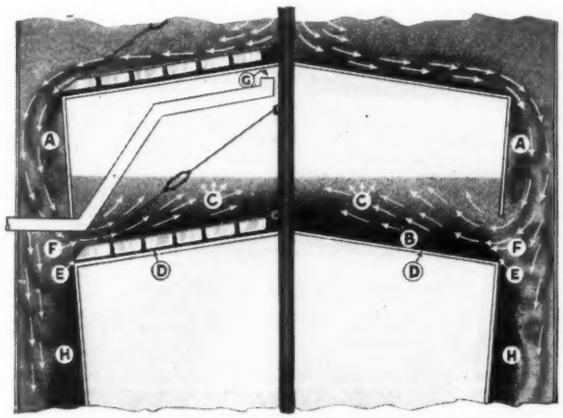


Illustration of Upward Sludge Filtration Method

GRAVER CLARIFIERS

Your clarifying problems will be effectively solved by the installation of a Graver Clarifier with UPWARD SLUDGE FILTRATION—the modern adaptation of an old principle. Write for full particulars on this outstanding equipment.

GRAVER builds—

PRESSURE FILTERS . . . GRAVITY FILTERS . . . CHEMICAL FEEDERS . . . PROPORTIONERS . . . LIME AND SODA WATER SOFTENERS . . . ZEOLITE WATER SOFTENERS . . . IRON REMOVAL WATER SYSTEMS . . . TASTE AND ODOR REMOVAL FILTERS . . . CLARIFIERS

GRAVER PROCESS MINERALS

GRACOLO—Processed Green Sand Zeolite for basic exchange.

GRACOHI—Hard, durable, high capacity Zeolite for basic exchange.

GRACOLITE—Synthetic Zeolite (gel type) mineral for basic exchange.

GRACARB—A non-siliceous Zeolite mineral for basic exchange.

GRAHICARB—A non-siliceous Zeolite mineral for acidic exchange. Can be used in combination with Gracarb for removing ionized dissolved solids from water.

GRACORRECT—For pH correction and stabilization of water supplies

Prices and complete specifications of any of the above minerals will be sent upon request.

ELEVATED STORAGE

The Value of Elevated Tanks on Water Supply Systems

By CHARLES BROSSMAN—Late Consulting Engineer*

Indianapolis, Indiana

In many cities the advantages of elevated water storage has been recognized, usually with considerable return on the investment.

On closed water systems without some form of storage facilities, where centrifugal pumps are in service, the pumps are usually installed large enough to take care of peak loads. It is quite evident that, with a pump available to take care of such peak loads, on the lighter loads (especially at night), the pump drops off greatly in efficiency, as does the motor. Such day in and day out waste of power mounts to an appreciable sum as time passes, until losses overbalance the costs of providing storage on the system —in instances many times over.

For instance: Assume a modern pump operating at full load efficiency of 70%, and motor at 90%. The unit will give a combined efficiency of 63%. This pump on the lighter loads, with a drop in efficiency of 50%, and the motor at 80%, gives a combined efficiency of only 40%, a difference between the two of 23 points.

It is readily realized that with such a condition recurring daily, the power consumption may be surprisingly increased for the year. Not alone such current waste, but if power is being purchased with a maximum demand charge on the motor size the rate will be increased due to this factor, for the reason that the pump motor must be large enough to take care of the peak load. On the other hand, an elevated tank will allow more uniform pumping, the pump and motor size can be reduced, thereby reducing the costly demand factor.

Another very evident disadvantage is that pressure is lost immediately whenever pump service is interrupted for any of several possible reasons. In case of fire such is disastrous. In any case, the public served is paying a penalty in insurance rates where pressure storage is not available on the system.

Furthermore, another advantage from elevated storage is that any pump on the line can be used at its maximum output, and with a correspondingly maximum efficiency. Pumps, therefore, can be purchased for use with elevated tank service over their maximum range of efficiency, with assurance that such efficiency can be realized in every day operation.

Another advantage is uniform pressure. With an elevated tank, automatic regulating control is available, whereby the tank variation in head may be kept within a few feet, thereby giving absolutely uniform pressures under all conditions of draft on the system. Particularly advantageous are elevated tanks in outlying districts, to reduce pumping costs and render better service pressures and flow. It is hardly necessary to indicate that more water will be used, in consequence, and a higher income enjoyed by the water utility.

In considering the values of elevated tanks for water storage it is apparent that there are a number of advantages.

Power Saving Case Records

The first advantage, that of saving in power cost, is the most appealing and in practically all cases a considerable saving in power will result. As a concrete example we may take the experience of a small plant in a town of 1,100 with which the writer is very familiar.

The Town of Albion, Indiana, had a water consumption of approximately 50,000 gallons per day. In this case an elevated tank was installed, the total cost of the tank being approximately $7,200.00. The power used before installing this tank, on the closed system, was approximately 1 KWH for 530 gallons; after the tank was installed, pumping was approximately 1 KWH for 1,050 gallons. This proved a spectacular attainment of cutting power consumption in half, but there are other Albions scattered over the country.

In this particular case, the tank will be paid for in less than 15 years by the saving in power bills alone. If the rate of consumption increases the time will be shorter, of course.

Here is a point of considerable interest in this case. Albion has its own generating plant, and the total cost of power is considered at 3c per KWH, including all costs. A careful check on all costs and power used still indicates the investment well justified. One reason is found in the fact that fire protection is now supplied with the small 200 G.P.M. pump and the large steam fire pump is no longer maintained as a ready to serve unit with fire in the boiler. Steam, however, can be had from the municipal power plant in case of necessity, and the pump is still available.

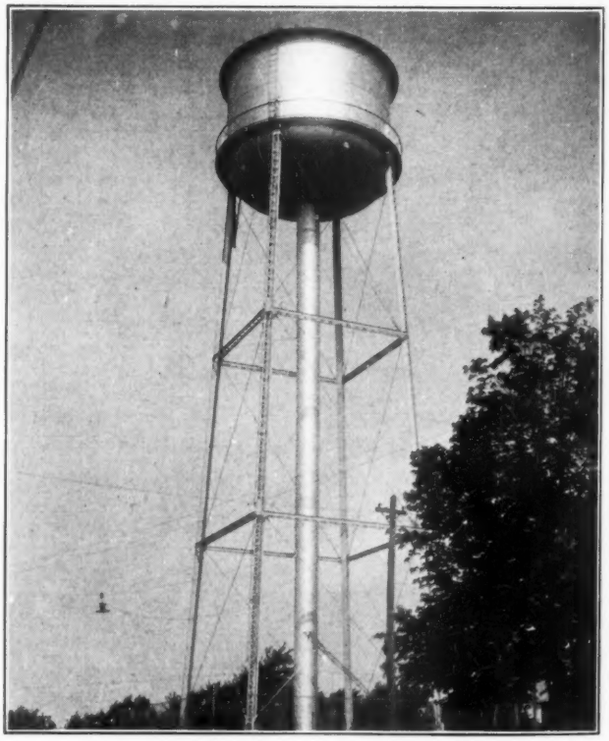
Another example is found in the City of Goshen, Indiana, where there has been installed a 500,000 gallon tank. The old plant was steam driven. About six years ago, the city installed a modern Diesel lighting plant, but only two of their deep well pumps were electrified at that time. The boilers had to be kept going at all times in the old steam plant, in order to have available suitable fire protection. In this case, a P.W.A. loan made it possible for Goshen to electrify its water works system. The city now has eight electric driven deep well pumps, and a new half million gallon tank. The loan by P.W.A. was negotiated on the basis of anticipated savings resulting from abandonment of the steam plant.

The cost of pumping for the old system on which boilers had to be kept up at all times, was given at approximately 8.3c per thousand gallons, which of course, was high, but the equipment was old, and used air lift pumps and double pumping, except for the two electric driven pumps.

It is estimated that the actual electrical pumping cost would be in the neighborhood of 1.2c per thousand gallons, and total cost at 2.2c per thousand. To take advantage of the potential saving (about 6c per thousand) an elevated tank had to be installed.

The old standpipe was not adequate for the demands, as the upper portion of this standpipe did not store very much water. The new elevated tank, of one-half million gallons, was installed some distance from the plant and on the opposite side of the city.

The entire pumping equipment is automatically controlled, there



The 50,000 Gal. Tank of Albion, Ind.
Will pay for itself in less than fifteen years.

* Excerpts from a paper written by Mr. Brossman shortly before his death. It was presented before the Indiana Section of A.W.W.A., but as far as we are aware it has never before been published.—Ed.

being two automatically controlled pumps at the tank site (about 1.5 miles from the main station), and six automatically controlled deep well pumps at the main station, each pump having a capacity of 500 G.P.M. Any pump can be manually started or stopped by push button control from the main plant.

Results at Goshen

Merle J. Miller, Superintendent and Manager of the Goshen plant, has made it possible for me to take the following from his report on the Goshen betterments.

"With a stand-pipe of the small capacity that we had previous to the erection of our new elevated tank, our water circuits were only fairly stable, but since the additional storage capacity has been added to our system, it has made a wonderful change in our water pressure charts as there is more cushion and no surge anywhere along the line. A number of charts taken at the elevated tank location have been absolutely perfect from the standpoint of surges or variation in pressure. We found before, especially with the steam pumping equipment, that we could detect each pulsation of the steam pump, as our standpipe capacity, at that time, was not enough to cushion the whole system properly. Comparing the old system as against the new system for uniform pressure, there is a vast difference. From the new system, if given any attention at all, we get a chart of uniform pressure, with as little variation as one pound.

"We also find a marked difference in the circulation of the water in districts where we had frequent complaints during the warm summer months against the warm stagnant water."

From the foregoing, it will be seen that in any plant that does not have an elevated tank, or if they have a standpipe of very small capacity, with very little water available in the upper section, the modern type of elevated tank, with all of the storage at the proper level, will almost invariably result in a financial saving, as well as give the other advantages which accrue to it.

Concerning Fire Protection Requirements

The relation of the elevated tank to fire protection is one of the important factors that should not be lost sight of. Modern elevated tanks, as compared to old standpipes, are much different for the available capacity for fire fighting facilities, as credit for water in a standpipe is only allowed for the top sections. Modern tanks, as now designed, keeps the water level to within a few feet variation, dependent more or less upon type of regulating control on the electric pumps.

Fire flows should not be confused with the total daily flow or capacity. For instance: if a town has a total available supply and storage based on a 24-hour period the fire flow will usually be based on a 5-hour flow for communities of 2,500 and less, which means that they will need 4.8 times the average consumption capacity as storage capacity for fire. For cities above 2,500 the multiplier will be 2.4 times for fire storage, as against consumer use storage. Such is based on a requirement of capacity for not less than a 10-hour period of continuous fire flow.

The fire flow requirements for average cities are given by the Underwriters, as follows:

Population	Required Flow (G.P.M.)
1,000	1,000*
2,000	1,500*
4,000	2,000
6,000	2,500
10,000	3,000
13,000	3,500
17,000	4,000
22,000	4,500
28,000	5,000
40,000	6,000
60,000	7,000
80,000	8,000
100,000	9,000

* For 5 consecutive hours; all higher flows for 10 consecutive hours.

Therefore, in selecting the tank the fire flow for the period required, according to population, is the primary consideration. To this must be added the domestic consumption.

One of the Two 1,500,000 *Gal. Tanks of Indianapolis*
A leafy green and silver structure which constitutes a study in "neighborhood-treatment" of water towers.

This amount indicated is then balanced against the available low lift capacity of the pumps, such as wells or filters, also the ground storage capacity. The total low lift and ground storage capacity is then determined.

The second step is to figure the high lift pump capacity and the elevated storage capacity.

After these two quantities are known, they are compared to the required fire flow and domestic flow over the 5 or 10-hour period, as the case may be. This will then give the ideal condition in installed pumping capacity and tank size.

In case these conditions are not met, if there is a deficiency in pumping capacity or storage on either the low lift and ground storage or high lift and elevated storage, this deficiency will be taken into account in the making of rates.

It should be clearly kept in mind that the total 24 hours available capacity is not what is considered by the Underwriters. They base the capacity wholly on the fire flows listed for the period of hours noted.

Concerning Tower Heights

The matter of pressure from elevated tanks should not be lost sight of, as various pressures are required for certain types of buildings, according to the size town and construction therein.

One of the outstanding tank installations in this country, is that installed by the Indianapolis Water Company.

This large tank is located in the eastern section of Indianapolis, which is approximately 100 feet higher than their main pumping station. With this long line of pipe, and the ensuing friction losses, pressures were previously very low in this district. It was decided, after considerable study of ground as elevated storage, to erect an elevated tank with 1,500,000 gallons capacity to serve the approximately 64,000 people in this district. This tank has resulted in great improvement in pressure and supply, with an ensuing satisfaction to the water consumers.

This tank is the largest one in the state of Indiana on a public water supply, the tank being 72 feet to the bottom, and with this large capacity, having a range of only 25 feet between the upper and lower water levels. As the result of benefits noted the Water Company is undertaking a tank of like capacity in another section.*

In conclusion, I would state that there are many plants on which a study of water storage as well as pump efficiencies connected therewith, would result in a marked saving in the operation of such plants.

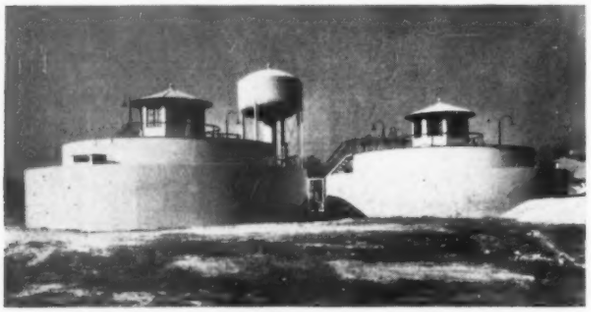
* Since the writing of this paper the second tank has been erected and placed in service. This installation, with the new Cathodic-protection system for safeguarding its interior against corrosion, is fully described in the November, 1939 issue of "WATER WORKS AND SEWERAGE."

BINS, Storage
BREECHING, Steel
CHUTES, Steel
FILTRATION PLANTS
FLUMES, Iron and Steel
GAS HOLDERS
HOPPERS, Steel
PENSTOCKS
PIPE, Riveted steel
PIPE, Welded steel

CHICAGO BRIDGE

Chicago.....2198 McCormick Bldg. Dallas.....1479 Liberty Bank Bldg.
New York...3390-165 Broadway Bldg. Birmingham.....1526 North 50th St.
Cleveland.....2262 Rockefeller Bldg. Tulsa.....1646 Hunt Bldg.

Plants in CHICAGO, Ill.; BIRMINGHAM, ALA., and GREENVILLE, PA.



Two 1,125,000 g.d. Morse Filter Plant units at Lorton, Va.

THE MORSE FILTER PLANT

The Morse Filter Plant is a rapid sand type plant, built entirely of steel. The filters, coagulating basins and reservoirs are located in concentric circles, providing a compact arrangement. The advantages are:

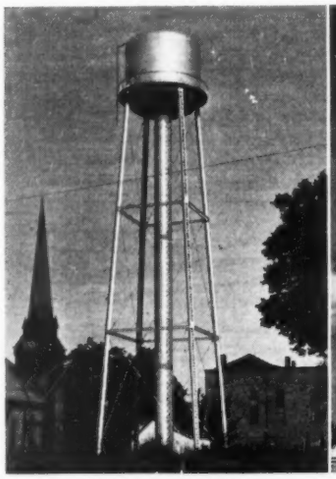
1. **All-steel construction offers the same advantages that have proved so desirable in water storage tanks. Ne seepage, no cracking, less maintenance expense.**
2. **Economical first cost. Requires less ground space per unit of capacity than any other type of construction.**
3. **Modern. Definitely designed to delay obsolescence.**
4. **Flexible in both operation and application. Put in capacity needed at present; add more capacity easily and economically at any time in future.**
5. **Lower operating costs. Small loss of head through plant. Cleaning and maintenance is easier and quicker.**
6. **Built in a wide range of capacities.**

FACILITIES

We are equipped to design, fabricate and erect all types of steel plate work, riveted or welded. When requesting estimating figures on tanks, state capacity, height to bottom for elevated tanks, and describe location.

INFORMATION

We are always glad to supply municipal officials and water-works engineers with complete information or estimating figures on any or all of our products. Address our nearest office. There is no obligation on your part.



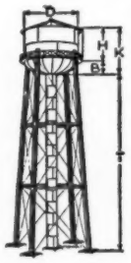
50,000-gal., Grass Lake, Mich.

200,000-gal., Hollywood, Fla.

ELLIPSOIDAL-BOTTOM ELEVATED TANKS

This type of tank is built in standard sizes as shown in the accompanying table. The tank diameter is relatively large and the depth shallow, reducing the variation in pressure between upper and lower water levels. Ellipsoidal-bottom tanks are available with two types of roofs; cone or ellipsoidal. Three typical cone roof tanks are illustrated below, and four tanks with ellipsoidal roofs and bottoms are shown above and to the right. This design provides a pleasing, modern appearance.

ELLIPSOIDAL-BOTTOM TANK SIZES



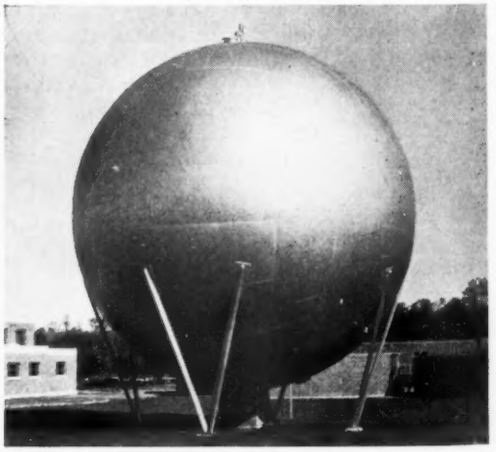
Nominal capacity, gal.	Tank dimensions			
	D	H	B	K
40,000	20'0"	13'9"	5'0"	18'9"
50,000	22'0"	14'0"	5'6"	19'6"
60,000	24'0"	14'0"	6'0"	20'0"
75,000	26'0"	15'0"	6'6"	21'6"
100,000	28'8"	16'0"	7'2"	23'2"
125,000	28'8"	21'2"	7'2"	28'4"
150,000	34'0"	16'6"	8'6"	25'0"
200,000	38'0"	17'6"	9'6"	27'0"
250,000	40'0"	20'0"	10'0"	30'0"
300,000	41'0"	23'9"	10'3"	34'0"
400,000	47'0"	23'2"	11'9"	34'11"
500,000	51'0"	24'3"	12'9"	37'0"
600,000	54'0"	26'3"	13'6"	39'9"
750,000	54'0"	32'0"	18'0"	50'0"
1,000,000	60'0"	34'0"	20'0"	54'0"
2,000,000	80'0"	35'6"	26'0"	61'6"

Height to bottom—any even foot.

50,000-gal., Mt. Palomar, Cal.

70,000-gal., Los Angeles, Cal.

250,000-gal., Brawley, Cal.



This 50-ft. diameter Hortonsphere is used to store sewage gas at 40 lbs. pressure at Sheboygan, Wis.

& IRON COMPANY

Houston.....2919 Main St. Boston...1548 Consolidated Gas Bldg.
Detroit.....1551 Lafayette Bldg. San Francisco.....1083 Rialto Bldg.
Philadelphia....1644-1700 Walnut St. Los Angeles.....1455 Wm. Fox Bldg.

In Canada: HORTON STEEL WORKS, LIMITED, Fort Eric, Ontario

PRESSURE VESSELS, Welded
RESERVOIRS, Steel
RECEIVERS, Air
SMOKE STACKS
STANDPIPES

STEEL PLATE WORK
TANKS, Elevated Steel
TANKS, Storage
TANKS, Surge
TANKS, Washwater

Three large capacity Horton radial-cone bottom elevated tanks are illustrated at the right. Capacities and locations are as follows (left to right): 500,000-gal., Holland, Mich.; 1,000,000-gal., Tucson, Ariz.; and a 1,500,000-gal. "Colonial" design unit installed at Hammond, Ind.

300,000-gal., Pleasant Hill, Md.

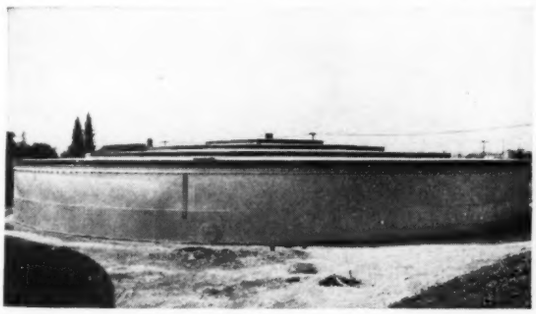
500,000-gal., Bristol, Penna.

RADIAL-CONE BOTTOM TANKS

The radial-cone bottom design was developed to permit the construction of large capacity tanks with a small range in head. (See installations shown above at Holland, Mich.; Tucson, Ariz.; and Hammond, Ind.) Radial-cone tanks are of sound structural design. They present a pleasing appearance. Construction details such as tower bracing, hand railing, etc., may be varied to secure the desired architectural effect. The accompanying table indicates the proportions for the various capacities.

STANDARD RADIAL-CONE SIZES

Capacity (Gallons)	Diameter of Tank	Depth of Tank
500,000	61′	25′
750,000	76′ 8″	25′
1,000,000	87′	25′
1,500,000	106′	25′
2,000,000	122′	25′



RESERVOIRS

Where natural elevations are available, flat-bottom steel reservoirs provide efficient gravity pressure. They are built in standard sizes or special designs to meet your requirements, of riveted or welded construction, with or without roofs.

Left: One of two 2,300,000-gal. all-welded steel water reservoirs installed at Alhambra, Calif.

100,000-gal. wash water tank at Michigan City, Ind.

WASHWATER TANKS

We build ellipsoidal, radial-cone or special shaped tanks to give exactly the capacity, head, and pressure variation required for washing filters.

SEWAGE GAS HOLDERS

When gas from digesters at sewage disposal plants is utilized, excess quantities produced during peak periods can be stored advantageously under pressure in a Hortonsphere for use during off-peak periods. Hortonspheres are relatively small in size and pleasing in appearance. We also build conventional lift-type gas holders.

300,000-gal., ellipsoidal-roof, flat-bottom water storage tank at Eden, New York.

MAINTENANCE OF TANKS AND STANDPIPES

By WILLIAM S. STAUB, Engineer
West Virginia Water Service Co.
Charleston, W. Va.

THE elevated tank or standpipe is one of the most costly single items amongst above-ground structures of a water system. Yet as a general rule they receive the least attention and very little is done in the way of yearly maintenance to keep the valuable units in first class condition. Tanks are generally located in inaccessible or out of the way places and the public is not afforded the opportunity to offer criticism of their appearance and, frequently, deteriorated condition. The condition of an isolated tank will generally provide a good barometer as to the condition of the remainder of any given water supply system. A well maintained tank represents to me that other structures and equipment comprising the system will be in good condition.

A tank is located in a distribution system to

1. Provide for peak demand.
2. Provide for uniform pumping head.

Peak demand may be subdivided into domestic, commercial, industrial and fire-demand. By providing some several hours of storage, we are able to operate with filtration plants, pumping equipment, etc. much smaller output capacities than otherwise. With adequate storage, properly placed in respect to the system design, conservative uniform output may be used which will make possible the performance and efficiency of pumping equipment at maximum economy and insured service expectancy.

Some Basic Considerations

Many maintenance worries may be eliminated by considering basic principles when plans are being drawn preliminary to tank erection. Proper foundations, anchorage, maintenance, accessories, painting and rigid inspection will prevent many abnormal maintenance worries.

Sufficient foundation should be provided that unequal settling and abnormal stresses in the tank may be eliminated. Heat, cold, wind, high and low water levels, all cause stresses in the tank that may tax the physical qualities of the material, without introducing those that may be prevented. The writer's company has built five standpipes at Charleston during the last two years. The largest of these was a riveted steel tank 100 feet in diameter, 52 feet high, with a capacity of 3,000,000 gallons.

Foundation and Bottom Important

All of these tanks have been constructed on foundations consisting of reinforced concrete rings. The foundations of these rings have been placed on rock and sufficiently anchored. The interior of the rings, upon which will rest the bottom plate of the tanks, have been built up of thoroughly compacted earth, capped with a 10 inch gravel mat and in turn capped with a 2 inch sand mat. The sand mat is always permitted to rise about 1 inch above the top level of the ring. This allows cushioned uniform settling when the weight of the full tank is superimposed. At the bottom of the gravel mat we have placed a grid system of 1 inch and 2 inch perforated galvanized pipe. Short nipples of this grid project through the concrete ring and are capped. After the tank has been constructed the voids in the sand and gravel are filled with oil through this grid system. In this manner it is possible to keep protective oil in contact with the bottom of the tank instead of water produced by sweating, rain or seepage, corrosively oxygen saturated.

The bottom plates of the tanks have been welded and we specify that an asbestos strip 6 inches wide be placed at each lap. Over this strip and the entire bottom of tank "No-Oxide" [A] Special or a similar substance is placed. The asbestos strip prevents the burning of the "No-Oxide" coating when the plates are being welded.

Sufficient anchorage is always used so that there will be no danger of the tank being overturned by a wind when emptied. In the event a tank is emptied, and there is any question as to sufficient anchorage provided, it is always a show of wisdom to guy the tank first.

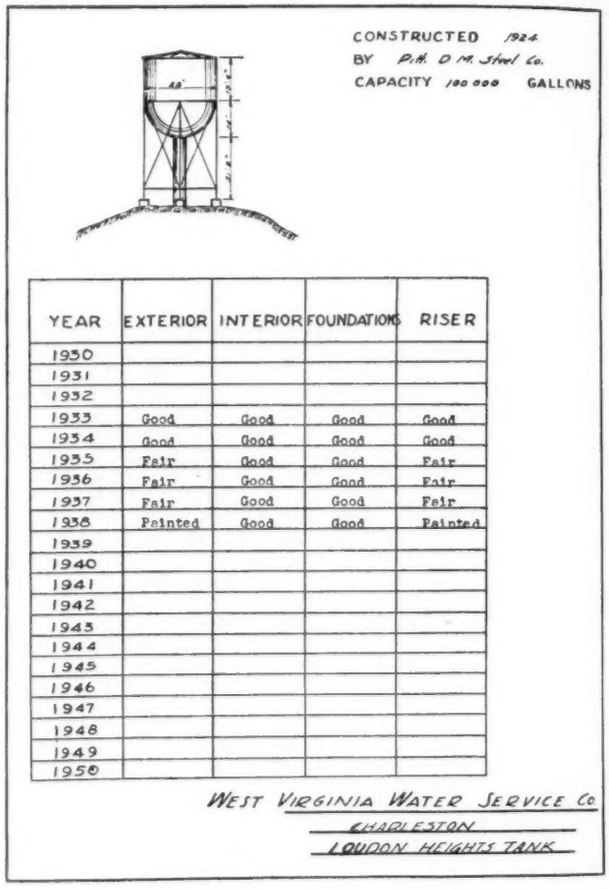
Miscellaneous Items

There should be provided on every tank an overflow of sufficient size to carry the water away in the event the control system should fail. The overflow line should be designed to preclude chokage or air binding. Landslides and damaged property are expensive items and there should be no risks in the design and maintenance of adequate overflow facilities.

Another very inexpensive item to be considered is a painting trolley. Rigging for cleaning and painting will be very simple with this adjunct provided, and the work can be done cheaper and safer. A trolley will save many dollars in later years.

In the shell of the tank, near the bottom, there should be a manhole of sufficient size to permit all material and equipment to pass when there is to be any cleaning or painting on the interior.

[It may also serve to save the lives of workmen as proved the case in a situation when a freshly coated tank caught fire in 1938.—ED.]



Specimen, Inspection Record and Sketch Sheet

An outside ladder should be provided so that the height of water in the tank may be checked, and the interior inspected, at any time. Also, to permit the paint trolleys to be moved when there is work being done on the tank. If the tank is high there should be a safety-cage placed around the ladder and some provision made at the bottom to prevent its becoming an attraction nuisance. The lower section of the cage may be covered with fine mesh heavy wire and a hinged gate or trap door should always be kept locked.

Cleaning and Coating or Painting

The item of painting is last but surely not least important. This item may cause a great deal of discussion. Different waters will act differently on the interior of tanks and varied conditions of the atmosphere will affect the exterior differently. For a number of years we have used on our tanks prime coats of red lead and a sealer coat of aluminum paint. The results have been very sat-

isfactory, but there are numerous coatings and paint producers who claim better results with other substances. Test specimens and time alone will prove the superiority of such substances. The 3,000,000 gallon tank previously mentioned in this paper was a very expensive tank and due consideration was given to the conditioning of the plates and to the painting. For your information the following section taken from the specifications will show the decision on the painting.

"The plates are to receive one shop coat of red-lead and the water side of all plates two field coats of red-lead of the following mix:

Paste red lead	100 lbs.
Boiled linseed oil	1½ gal.
Fine powdered litharge	8 lbs.
Turpentine	¾ gal.

The outside of plates are to receive one shop coat of red-lead and one field coat of red-lead of a mix of the following proportions:

Paste red lead	100 lbs.
Raw linseed oil	2⅛ gal.
Drier	1 qt.
Turpentine	1 qt.

The outside of the shell and roof will receive two field coats of Aluminum Graphite Paint."

We believe that this is the best paint job ever applied on any of our tanks and we are using these specifications on all new construction and also on maintenance jobs.

An Inspection System

At the present time we have 6 elevated steel tanks and 13 steel standpipes at our different plants throughout West Virginia. We use an inspection and report system that will enable us to keep a close check on the condition of these tanks. From the annual report of the plant superintendent on the forms provided, and from our personal inspection we provide in the budget for any maintenance that the tanks must receive. By this method it is also possible to keep a record showing the results obtained by the previous protection applied.

Cleaning Practice

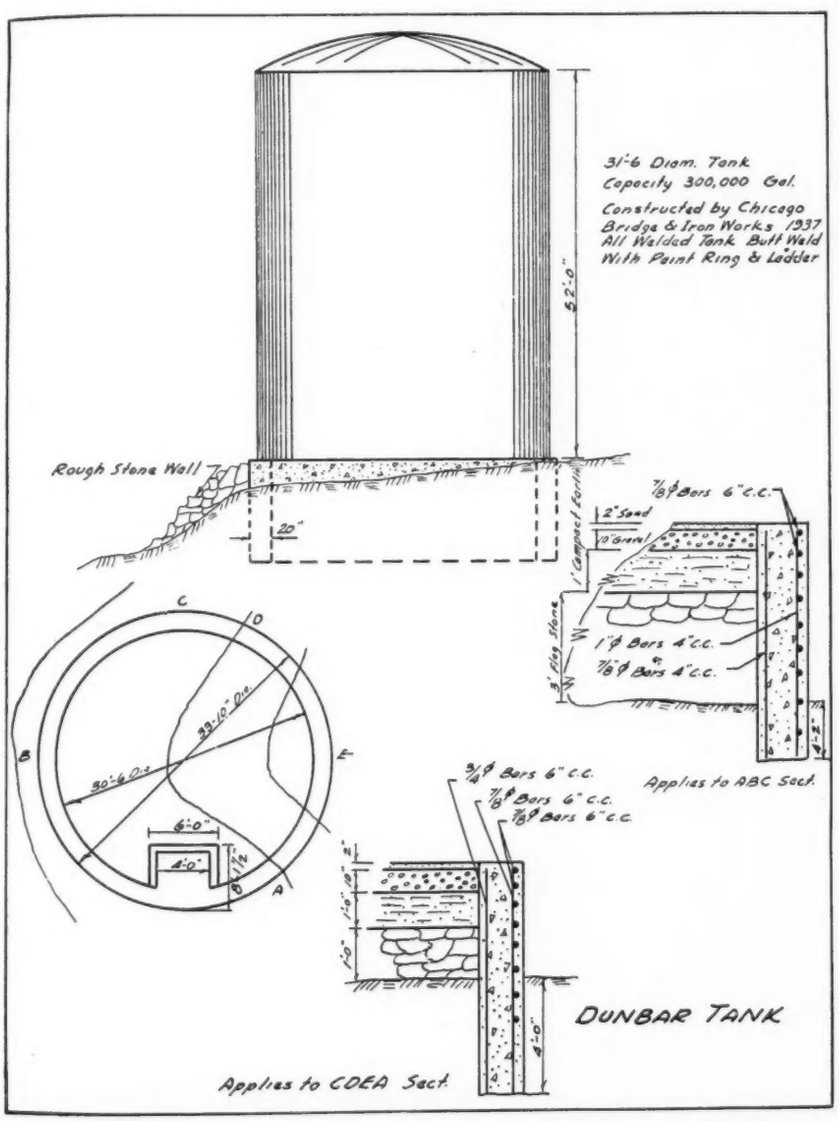
The cleaning of a tank is by far the most costly item in tank maintenance. It is worse than useless to paint an improperly cleaned tank. It has been our policy to secure a good clean metal before any primer is applied. There has been some difficulty and expense in doing so, but our experience shows that an improperly cleaned surface will blister and peel within a year after paint is applied. We are using at the present time an Aurand cleaning tool, operating on compressed air, that has given fine results. This tool weighs but 7½ pounds and is not burdensome to those using it. It is composed of a rotary cylinder on which circular blades are loosely fit. These blades are replaceable, and it is also possible to replace these scraping blades with wire brush wheels. The tool can also be purchased to operate electrically. For further information the reader may wish to write the manufacturer, the following address being given for the purpose:

Aurand Mfg. & Equipment Co.,
Box 83 S. Y.,
Cincinnati, Ohio

The most expensive single item in cleaning is the tower legs on the elevated tanks. Due to the fact that the intricate lattice bars are spaced so close that it is difficult to clean properly with any form of tool. To properly clean a 35 foot tower leg costs approximately $45.00. With four or six legs, the cleaning cost of an elevated tank is unreasonably high. If we were to construct an elevated tank we would investigate thoroughly the possibility of using a single column for the legs. If this were not possible a plate would be substituted for the lattice bars of a built up member. The cost of the additional weight of steel would certainly be classed as a credit to maintenance.

Accompanying this paper are specimen record sheets of tanks, such as we use for field work, maintenance estimates, and a general perspective of the tanks. These sheets, kept in a bound folder, serve to reveal a very useful case history on each tank and record the effectiveness of the type of maintenance given.

I should like to suggest that the "Standard Specifications for Riveted Steel Elevated Tanks and Standpipes," published by the American Water Works Association, be consulted by anyone thinking of future tanks. These specifications serve effectively as the base for more detailed specifications.

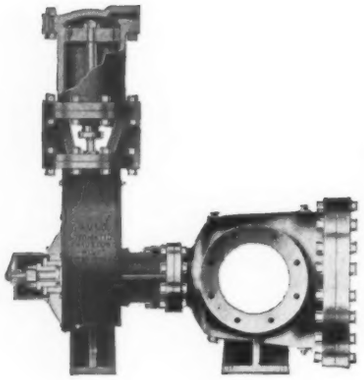


Specimen, Design Sketch Which Is Kept in Tank Binder with Inspection Record Sheets

GOLDEN-ANDERSON VALVE SPECIALTY CO.

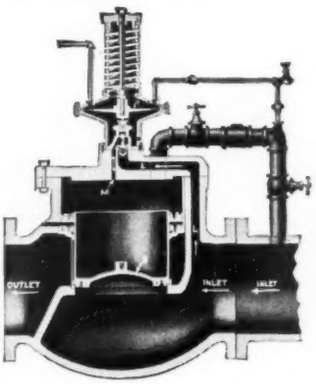
1350 Fulton Bldg.

PITTSBURGH, PENNA.



THRU-FLOW CONE VALVE

Afford full pipe line flow without friction loss. Always oil lubricated. Axially unseats before it rotates without friction, rub or wear. Especially desirable for sewage disposal service.



ALTITUDE CONTROL VALVE

Assures uniform water level in tanks, standpipes and reservoirs. Suitable for use in single or two-way line service. Heavy internal bronze mounting and air and water cushioning makes valve indestructible. Sizes to 24″.

CUSHIONED FLOAT VALVE

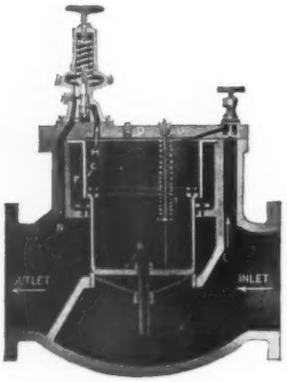
Automatically maintain uniform water levels in tanks, standpipes, etc.

Instantly adjusted to operate quickly or slowly.

Cushioned by water and air, sizes ½ to 24″.

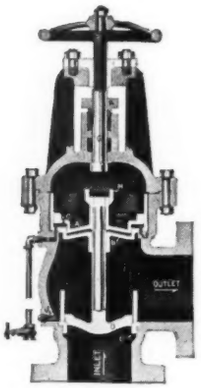
CONTROLLING FLOAT VALVE

Ideal for heaters, vats, tanks, etc. Valve entirely self-contained and operates without water spill. Sensitive in operation and indestructible due to air and water cushioning and heavy bronze mountings. Sizes to 24″.



WATER REDUCING VALVE

Assures positive control of low pressure. Air and water cushioning prevents shock or hammer. Supplied with single or dual pilot controls for any service. Sizes to 24″.

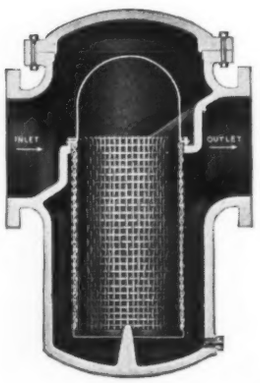


NON-RETURN VALVE

Protect life and property against boiler tube ruptures; also, furnished in Triple Acting style to protect against steam line breaks. Supplied for low and high pressure steam service. Sizes to 12″ in angle, globe or elbow patterns.

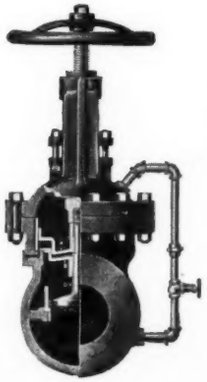
WATER STRAINER

Large capacity with minimum friction loss. Strainer basket quickly accessible and easily cleaned. Basket mesh furnished to suit any service conditions. Sizes to 24″.



ENGINE STOP VALVE

The most efficient and dependable automatic stop valve to prevent overspeeding of turbines, engines, etc. Automatically tripped by mechanical or electrical control. Furnished angle or globe patterns to 12″ sizes.



CATHODIC PROTECTION* FOR WATER WORKS EQUIPMENT

By WM. D. LOREAUX
Superintendent, Water Department
Dundee, Michigan

No one knows better than the waterworks operator just what havoc is wrought upon metallic surfaces by the action of water.

We have painted wash troughs, wash water and elevated tanks but, as has been stated in a previous conference[1] the perfect paint for continuously or intermittently immersed waterworks appurtenances has yet to be developed.

Painting of wash troughs and the interiors of wash water tanks and elevated tanks on distribution systems is a real problem, since to do so entails taking out of service for a period of time, a very essential piece of apparatus. Unfortunately painting must be repeated at more or less regular intervals to secure effective protection. In addition to the inconvenience of having the piece of apparatus idle, the cost of painting is greater than is commonly appreciated. Those who have adequate records of this maintenance practice can attest to this fact.

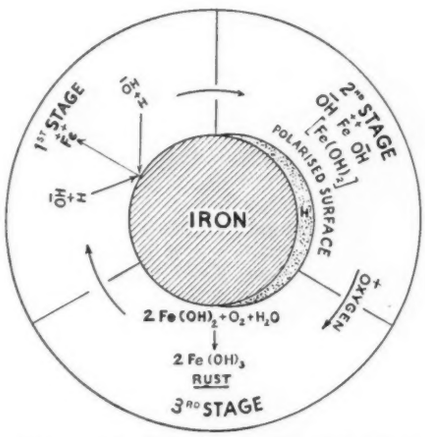


Fig. 1. The Progress of Corrosion and Rusting, Graphically Pictured.
The 1st stage is that of solution and ionization of the iron in which small D. C. current flow is produced—such flow being subject to reversal by opposing current input. The 3rd stage is that of oxidation by dissolved oxygen and visible rusting. Rust is the return of metallic iron to its native state, the oxide, and is in reality nature's "scab" that forms over the "sores" of corrosion.

In the case of elevated steel storage tanks, it is almost expecting the impossible to get a paint job that will give protection for more than a short period of time. Despite thorough scraping and wire brushing to remove loose paint, scale and rust, the job usually has to be done under such pressure and hurry that it cannot be done as thoroughly as it should be. A piece of old scale or rust, or lose paint, under which there may be more or less moisture, gives a poor surface for painting. And also, to withstand the extremes of temperature from the sweltering suns of summer to the subfreezing temperatures of winter, requires a paint of many accommodations.

The Theory of Rust Formation

Allan A. Pollitt (3) explains the formation of rust as follows:

"The first stage in the mechanism of the corrosion, involving pure iron, pure water and pure oxygen only, is the transfer of charges from hydrogen ions to the metal. The latter thereby enters solution and continues to do so until the polarization, due to the film of gaseous hydrogen deposited on the metal surface, is sufficient to arrest the process. This stage (see diagram) may be represented by:

$$1.\quad Fe + \begin{matrix} H'\text{-}OH' \\ H'\text{-}OH' \end{matrix} = Fe'' \begin{matrix} OH' \\ OH' \end{matrix} + H_2 \text{ (Gaseous Hydrogen)}$$

The liquid medium at this point is virtually a solution of ferrous hydroxide, $Fe(OH)_2$, ionized, of course, and the final stage consists in the oxidation and precipitation of this as ferric hydroxide or rust:

$$2.\quad 4Fe(OH)_2 + O_2 + 2H_2O = 4Fe(OH)_3 \text{ (Rust)}$$

This precipitation of ferric hydroxide disturbs the equilibrium of the system, and, in conjunction with the second effect of the oxygen which, by combining with and removing the polarizing film of hydrogen (gas), depolarizes the metal surface, results in the continued solution or corrosion of the metal. The entire process may be visualized by referring to Fig. 1, in which is a schematic presentation of the phenomena. In the first stage we have the metal shooting off ions into the water and the development of the polarizing film of hydrogen gas. This continues until stopped by the polarization, and we have the condition represented by stage two, in which the liquid at the metal surface is virtually a solution of ferrous hydroxide. In the third stage occurs the oxidation of the ferrous ions and their precipitation as rust, and also the depolarization of the metal surface. This brings us back again to the beginning of the cycle."

The Prevention of Rusting by Cathodization

When a steel water tank, or pipe, is filled with water it automatically becomes the equivalent of a galvanic battery which will give both voltage and amperage readings on electrical measuring instruments. The result is corrosion and the visible evidence of such—rusting.

It is reasonable then to believe that this form of corrosion can be stopped by reversing the electrolytic forces that cause it. There are now on the market electrical rectifier units that convert A.C. to D.C. current and apply such electro-plating current in proper intensity to maintain the steel tank and riser in an electroc-negative (cathodic) state, (Fig. 2 and Fig. 3). Thereby positive ions such as hydrogen, calcium, iron, etc., migrate by electrolytic attraction to the steel walls, where they form an insulating film. So long as the proper potential difference is maintained by the flow of current these protective positive ions are held on the negative pole—namely the interior

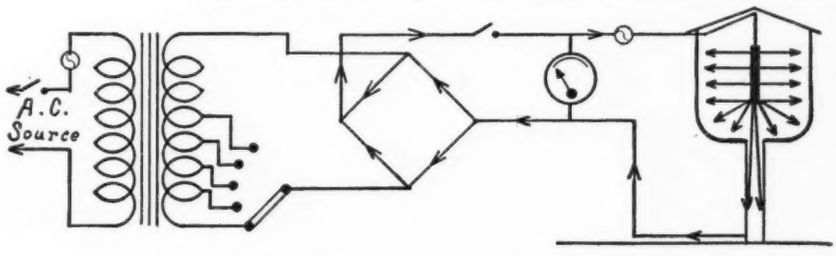


Fig. 2. A Schematic Sketch of Cathodic Protection.
This "flow sheet" indicates the conversion of A. C. to D. C. current in passing through the rectifier (left); flow as D. C. through the suspended anode in the tank (right) and its travel radially through the electrolyte (water) as a plating current to the cathode (tank walls). The ions of hydrogen and metals in general (notably calcium) are plated out on the tank surface or on any other submerged metallic surface which has a conductive ground connection.

walls of the tank. Perhaps the most effective phase of cathodic protection is found in the fact that the thinner the protective coating over the metal, the stronger is the electro-plating effect at such spots. Therefore the current flow is automatically directed by the laws of electro-chemistry to build protection at the weakest points. It is merely the exhibition of the law that current always flows through the paths of least resistance. Thus, if a crack develops in a protective coating or film there follows an immediate rush of current flow to the spots where the healing current is most needed.

The principle of cathodic action is not new but its application for the protection of water mains, tanks, etc., is quite recent. This means of protection was probably first applied to water mains in New Orleans, but has had its greatest application in protecting steel gas and oil lines in the southwest.

Thayer (4), with considerable experience in perfecting the method states in an article in "Waterworks & Sewerage" for August 1938: "It has been proved that regardless of the cause of the corrosion on the pipe, the action is the same. Currents are generated in the pipe itself. These currents flow in the pipe wall to areas where they discharge into the soil.

"As they leave the pipe they take metal with them. These currents are very small but they may be and generally are discharged in small areas. When it is realized that one ampere leaving a pipe wall will take twenty pounds of metal with it within a year, it is seen that a very small part of an ampere will do much damage when confined to a small area.

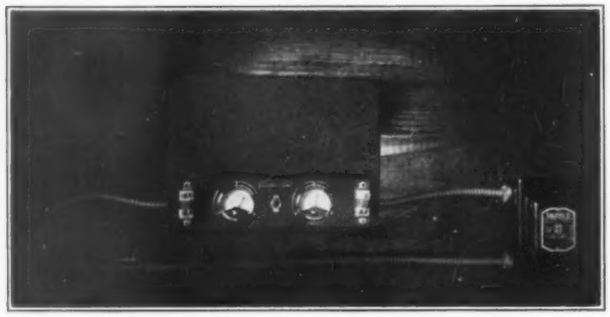


Fig. 3. Compact A.C-D.C. Rectifier Such as is Supplied by Electro-Rust Proofing Co.

"The principle of cathodic protection is simply this: a current is caused to flow from the surrounding soil onto the pipe wall in sufficient strength to block those currents which are trying to leave the pipe. When this is done corrosion will cease. To make this a little plainer, suppose that it is water which is flowing through the pinholes in the pipe wall and off into the soil. If it were possible to build up a pressure in the surrounding soil of sufficient intensity then there would be no more water to leave the pipe. Of course, that is impossible but it is possible when dealing with electrical pressure to do the equivalent.

"To cause the current to flow onto the pipe wall it is necessary to have a source of direct current. The positive terminal of the source of direct current is connected to a mass of junk iron buried in the soil not far from the pipe to be connected. The negative terminal is connected to the pipe.

"As the current is forced from the scrap metal, it passes through the soil and onto the pipe and is returned through the wall of the pipe and the connecting wire to the source of current."

Cathodic protection for elevated steel storage tanks, wash water tanks, steel wash troughs and pumps is of more recent date than its application to pipe lines. It is believed that the first installation on a water tank was at Dayton, Ohio in 1936. This was followed by an installation at St. Clairsville, Ohio (5). At Dundee we installed the system in November, 1938. At Monroe, Mich. a system was installed on the wash water tanks in December, 1938 and since Monroe has been experimenting with cathodic protection for the wash water troughs. The Indianapolis Water Co. has equipped a large new elevated tank and Milwaukee recently installed the system on a 6,000,000 gallon tank.

The required equipment is simple, consisting essentially of a compact transformer-rectifier set, the hanging tank electrode and the necessary wiring. The negative terminal of the transformer-rectifier set is connected to the riser pipe and the positive terminal to the insulated suspended electrode. (See Fig. 2.)

At the time of installation, we put in two pieces of test metal. One was in the electrical circuit and the other not so connected. Both were immersed in the tank water. On January 3rd, (forty days later), both pieces of test metal were removed and it was found that the piece immersed in the water but not connected in the electrical circuit was rusting markedly. The other piece (that connected in the electrical circuit) had a well defined gray coating of what appears to be calcium carbonate. It showed no signs of rust beneath the coating.

Operating Costs

The cost of installation of the system varies with the size of the tank. The Dundee installation cost $250.00 for a 50,000 gallon tank, whereas that at St. Clairsville, Ohio, cost $325.00 for a 200,000 gallon tank, according to an article in "Waterworks & Sewerage" (5).

The cost of power for operating the rectifier at St. Clairsville (at 2 cts. per kwh.) has been about 40 cts. a month. Our costs (at 5 cts. per kwh.) have averaged $1.80 per month during the first eight months. For a small tank this is somewhat higher than we had anticipated. Whether such is due to the condition of our tank or other causes has as yet not been fully determined. We were told that current consumption should decrease as the rust is removed and the polarization becomes more complete. This statement appears to be holding true, since our daily current consumption is now 1.2 kwh. as compared to the maximum of 2.3 kwh. in the first month the system was in operation.

Conclusions

Although cathodic-protection is yet young, indications are that it may be applied with benefit to practically all kinds of metallic waterworks equipment subjected to under water or soil corrosion.

Whether cathodic-protection is a complete or only partial answer to the water operator's prayer will require a little more time for adequate demonstration. If it *is* the right answer, then our pipe line, wash water trough, stilling apron, elevated tank and pump corrosion troubles should become a thing of the past.

References

[1] "Waterworks Paints," Richardson, Twelfth Annual Michigan Conference on Water Purification.

[2] The Rusta-Restor Corporation. Correspondence and literature, from which some of the accompanying sketches were derived.

[3] "The Causes and Prevention of Corrosion," by Alan A. Pollitt.

[4] "Cathodic Protection," by Starr Thayer, *Water Works and Sewerage*, August, 1938.

[5] "New Method of Tank Protection," by O. B. Hess, Superintendent, St. Clairsville, Ohio, *Water Works and Sewerage*, November, 1938. (Also in the Reference and Data Section of the May, 1939, issue, page 195.)

*The content of this article is in part derived from a paper read by the author before the Michigan Section of A.W.W.A. and Michigan Conference on Water Purification meeting jointly.

TABLE OF EFFECTIVE FIRE STREAMS

Using 100 feet of 2½-in. ordinary best quality rubber-lined hose between nozzle and hydrant or pump.

Smooth Nozzle, Size	¾ Inch					⅞ inch				
Pressure at Hydrants, lbs.	32	43	54	65	75	86	34	46	57	69	80
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	2	3	4	5	5	6	4	6	7	9	10
Vertical Height, feet	48	60	67	72	76	79	49	62	71	77	81
Horizontal Distance, feet	37	44	50	54	58	62	42	49	55	61	66
Gallons Discharged per min.	90	100	116	127	137	147	123	142	159	174	188

Smooth Nozzle, Size	1 Inch					1⅛ Inch				
Pressure at Hydrant, lbs.	37	50	62	73	85	97	41	54	67	80	93
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost 100' 2½" hose	7	10	12	13	15	17	11	14	17	20	23
Vertical Height, feet	51	64	73	79	85	89	52	65	75	83	88
Horizontal Distance, feet	47	55	61	67	72	76	50	59	66	72	77
Gallons Discharged per min.	161	186	208	228	246	263	206	238	266	291	314

Smooth Nozzle, Size	1¼ Inch						1⅜ Inch				
Pressure at Hydrant, lbs.	46	60	75	90	104	119	52	69	86	102	119
Pressure at Nozzle, lbs.	30	40	50	60	70	80	30	40	50	60	70
Press. lost per 100' 2½" hose	16	20	25	30	34	39	22	29	36	42	49
Vertical Height, feet	53	67	77	85	91	95	55	69	79	87	92
Horizontal Distance, feet	54	63	70	76	81	85	56	66	73	79	84
Gallons Discharged per min.	253	292	326	357	386	413	307	354	396	434	469

PITTSBURGH-DES MOINES STEEL CO.

Tanks—Plate Fabrication—Structural Steel

Sales Offices at: 3418 NEVILLE ISLAND, PITTSBURGH, PA. . . . 919 TUTTLE STREET, DES MOINES, IOWA
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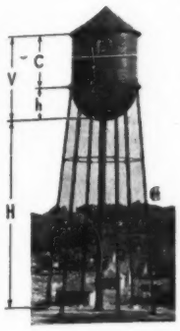
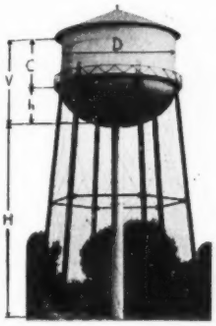
In these tables we have compiled—in compact but complete form—data on steel reservoirs and on the various types of elevated steel tanks. For information as to the application of these various types of tanks, for designs, for specifications, or for estimates—write our nearest office.

Table I—Pittsburgh-Des Moines Standard Hemispherical Bottom Elevated Tanks



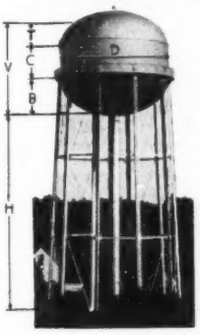
Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity													
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
5,000	9	10 0	11 3	11 3	18 9	31 9	38 3	51 9	58 9	72 9	79 9	93 9	100 9	.....	.....	.....	.....
10,000	13	5 11	11 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
15,000	13	10 11	16 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
20,000	13	15 11	21 11	10 0	20 0	30 0	40 0	50 0	60 0	70 0	80 0	90 0	100 0	.....	.....	.....	.....
25,000	15	14 7	19 11	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	.....	.....
30,000	15	18 5	23 9	44 8	50 0	69 8	75 0	.....	94 8	100 0	.....	125 0	.....	.....	.....	.....	.....
40,000	17	18 5	25 1	46 8	.....	.....	75 0	.....	96 3	100 0	.....	125 0	.....	.....	.....	.....	.....
50,000	19	17 7	25 7	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
60,000	19	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
75,000	21	22 6	30 6	.....	55 0	63 4	75 0	83 4	91 8	100 0	111 8	120 0	128 4	140 0	148 4		
100,000	24	22 6	31 0	.....	50 0	63 1	75 0	79 7	91 6	100 0	113 1	116 6	125 0	141 6	153 4		
150,000	28	24 2	34 7	46 6	54 10	63 2	75 0	83 4	91 8	100 0	111 10	120 2	128 7	140 2	148 7		
200,000	32	23 4	36 1	45 9	54 1	62 5	75 0	83 4	91 8	100 0	112 7	120 11	129 3	141 10	150 2		
250,000	32	31 4	45 4	45 4	53 8	62 0	75 0	83 4	91 8	100 0	113 0	121 4	129 8	142 8	151 0		
300,000	36	28 4	42 5	45 4	53 8	62 0	75 0	88 4	91 8	100 0	113 0	121 4	129 8	142 9	151 1		
400,000	40	30 0	46 6	44 6	52 10	61 2	75 0	83 4	91 8	100 0	113 10	122 2	130 6	138 10	152 8		
500,000	44	29 9	49 2	43 6	51 10	60 2	75 0	83 4	91 8	100 0	114 10	123 2	131 6	139 10	154 7		
600,000	44	38 6	58 2	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.													
750,000	50	34 9	57 5														
1,000,000	50	52 0	73 9														

Table II—Pittsburgh-Des Moines Standard Hemi-ellipsoidal Bottom Elevated Tanks



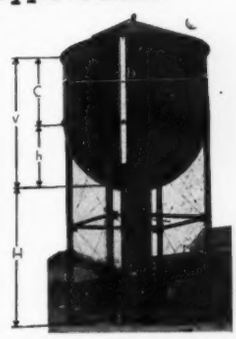
Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft. in.	V ft. in.	H = Height of Tower to Bottom of Tank Capacity													
				ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
25,000	17	11 9	15 5	46 4	51 8	71 4	75 0	.....	96 4	100 0	.....	126 8	...	.....	.....	.....	
30,000	17	14 7	18 6	46 1	51 5	71 1	75 0	.....	96 1	100 0	.....	126 5	.....	.....	.....	.....	
40,000	21	11 3	16 9	47 5	.....	.....	75 0	.....	97 5	100 0	.....	126 2	.....	.....	.....	.....	
50,000	22	13 2	19 0	.....	57 2	65 6	75 0	85 6	93 10	100 0	113 10	122 2	130 6	142 2	150 6		
60,000	24	12 10	19 4	.....	56 6	64 10	75 0	84 8	93 2	100 0	113 2	121 6	129 10	141 6	149 10		
75,000	26	13 6	20 8	.....	55 10	64 2	75 0	84 2	92 6	100 0	112 6	120 10	129 2	140 10	149 2		
100,000	28	16 2	23 2	.....	51 6	64 7	75 0	81 1	93 0	100 0	114 7	118 0	126 6	143 0	154 10		
150,000	34	14 10	25 0	46 9	55 1	63 5	75 0	83 7	91 11	100 0	112 1	120 5	128 9	140 6	148 10		
200,000	38	15 5	27 0	46 11	55 3	63 7	75 0	84 6	92 0	100 0	113 9	122 1	130 5	143 0	151 4		
250,000	40	18 1	30 0	47 5	55 9	64 1	75 0	85 5	93 9	100 0	115 1	123 5	131 9	140 1	153 1		
300,000	40	23 11	34 0	49 4	57 8	66 0	75 0	87 4	95 8	100 0	117 0	125 4	133 8	142 0	155 0		
400,000	46	22 9	34 11	48 10	57 2	65 6	75 0	87 8	96 0	100 0	118 2	126 6	134 10	143 2	157 0		
500,000	50	23 9	37 0	49 8	58 0	66 4	75 0	81 2	89 6	100 0	112 8	121 1	129 4	146 0	152 5		
600,000	55	21 9	39 7	Tower heights have not been standardized for these capacities and can therefore be built to suit the requirements in each particular case.													
750,000	60	22 4	42 4														
1,000,000	60	35 0	54 0														
1,000,000	65	26 1	47 7														
1,250,000	79	17 4	43 4														
1,500,000	70	37 8	60 0														
1,500,000	79	24 0	50 0														
2,000,000	90' 3"	22 6	50 0														

Table III—Double Ellipsoidal Tanks



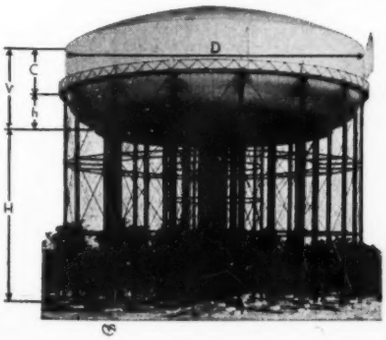
Capacity in U. S. Gallons	Tanks D ft.	V ft.	V in.	H
100,000	28	23	8	
150,000	34	26	9	
200,000	38	27	7	
250,000	38	33	7	
275,000	40	33	2	Built to Order
300,000	42	31	7	
350,000	44	36	6	
400,000	46	35	7	
500,000	50	39	2	
600,000	54	40	0	
750,000	Dimensions on request			
1,000,000				

Table IV—Railroad Type Tanks



Capacity in U. S. Gallons	Tank Dimensions D ft.	C ft.	C in.	V ft.	V in.	H
20,000	15	10	9	16	2	
25,000	15	14	7	19	11	
30,000	17	12	7	19	0	
40,000	19	13	1	20	6	Any height from 15' 0" to 40' 0" in multiples of 5' 0"
50,000	21	13	1	21	1	
60,000	24	10	1	20	3	
75,000	24	15	1	23	10	
100,000	28	13	5	23	7	
150,000	28	14	2	24	7	
200,000	36	15	1	29	2	
250,000	38	17	3	33	3	
300,000	38	23	11	38	3	

Table V—Toroidal Bottom Tanks



Capacity in U. S. Gallons	Tank Diameter (D) when h = 10' 0" and V = 20' 0"		V = 25' 0"		V = 30' 0"		V = 35' 0"		H
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	
750,000	82	0	73	2	66	8	61	8	
1,000,000	94	5	84	3	76	9	71	0	
1,250,000	105	4	94	0	85	8	79	2	Built to Order
1,500,000	115	2	102	9	93	9	86	8	
2,000,000	132	8	118	5	108	0	99	11	
2,500,000	148	0	132	3	120	7	111	6	
3,000,000	162	0	144	8	131	11	122	1	
4,000,000	186	8	166	9	152	2	140	9	
5,000,000	208	6	186	3	169	11	157	3	

Table VI—Steel Reservoirs

Capacity in U. S. Gallons	Diameter ft.	Height ft.	Height in.
50,000	24	15	1
75,000	24	22	7
100,000	30	19	3
125,000	30	24	0
150,000	36	20	1
175,000	36	23	4
200,000	36	26	8
300,000	42	29	4
400,000	42	39	1
500,000	48	37	5
600,000	60	28	10
750,000	72	25	0
1,000,000	84	24	6
1,500,000	96	28	1
2,000,000	120	24	0
2,500,000	132	24	10
3,000,000	144	25	0
4,000,000	168	24	6

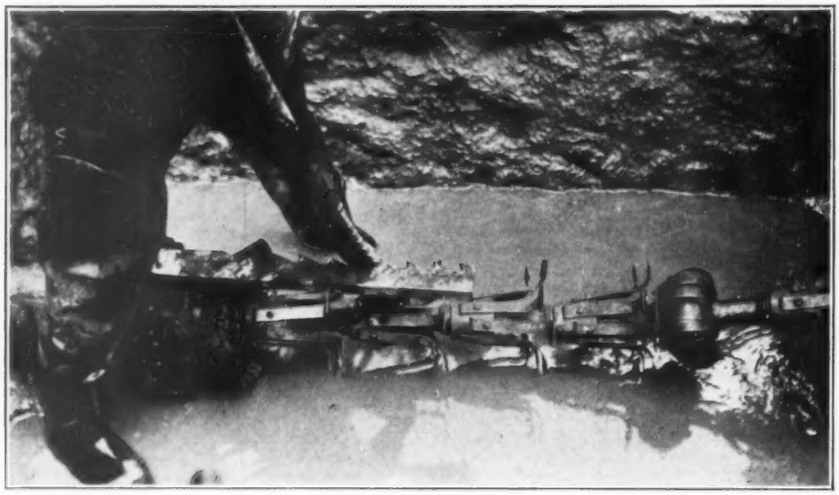
WATER MAIN CLEANING

Some Recent Experiences and Results

By WM. S. STAUB, Engineer

West Virginia Water Service Co.
Charleston, West Virginia

WE HAVE just completed main cleaning projects at three of our properties in this state. This, our first adventure in this kind of main restoration, will serve as index of merit of the process. We have definitely raised the flows and pressures in those mains that have been cleaned and, in cases of the transmission mains, the pumping cost per million gallons has been reduced.



"Jacking-In" Operation

About half of a cleaning tool jacked into an 8-in. main. It will travel under its own "steam" by main pressure turned in behind it.

The purpose of this paper is to present our ideas of main cleaning, why we clean mains, what results we have had, the cost per foot to clean; to give a general description of the procedure and to observe what happens in a cleaned main.

In years gone by, when there was no water treatment or when the practice was in its infancy, beyond taste and appearance other characteristics of the water were given little thought. Therefore the distribution system suffered, due to lack of knowledge of corrective treatment. Th edeposition of the solids and the tuberculation reduced the area of the pipe and, therewith, the amount of water that would flow through the pipe under pressure available. Consequently, today, when there are complaints of poor pressure, or when increased fire flow is in demend, we are faced with the problem of main replacements or improvement of existing mains. Although the exterior of the pipe is usually as good, practically, as the day it was installed, the interior may present a scene comparable to the stalagmites and stalactites of the eastern caverns. If such choking deposits can effectively be removed from the pipe and the carrying capacity appreciably restored there will be a great savings over replacements, even though the latter be necessary eventually..

A dirty main is definitely a liability. From the operating standpoint a dirty transmission main consumes many kilowatt hours of power due to the added friction. Kilowatt hours in turn cost money, which in turn increases operating expenses. A dirty main is a great handicap to the fire departments, due to insufficient quantities of water. Poor pressure complaints from consumers are not soothing melodies to a superintendent's ears. Consequently, everyone suffers from the effects of tuberculated pipes.

Locating the Trouble

When a main is suspected of being tuberculated, or when we find that the operating head on a pump is much greater than the static head plus the calculated friction head for new pipe, it is time to find the trouble. The distribution main is isolated in such a manner than all water going to a certain area must pass through the section of pipe to be tested. Then, in the early morning hours, the calibrated pressure gauges are placed along the line and a hydrant is opened at the end of the line. The amount of water is measured with a pitot-tube, the pressure drop is recorded and the loss per 1000′ or the value of "C" is determined. (For details of the method see "Hydrant Discharge Measurements," page 183. Reference and Data Number of Water Works and Sewerage, May, 1939.)

We admit this method of determining "C" is not as accurate as secured by Pitometer tests, but we feel that a reasonably accurate value is obtained if precautions are used. In the case of transmission mains, by determining the efficiency of the pumping equipment, static head, operating head, power consumed, water pumped, it is possible to get a very good check over any period. (For "A Simple Method for Checking Pump Efficiencies" see page 445, November, 1939, Water Works and Sewerage.)

Cleaning Procedure

The largest pipe which we cleaned was 10″ cast iron. The 10″ and 8″ pipe was cleaned with the pressure cleaning machine, which uses the water pressure to push the device through the pipe. This machine (see pictures) is about 6′ long, composed of five cutting heads and two pistons. The heads are "vertebrae" upon which are attached, around the circumference, the cutting blades. The

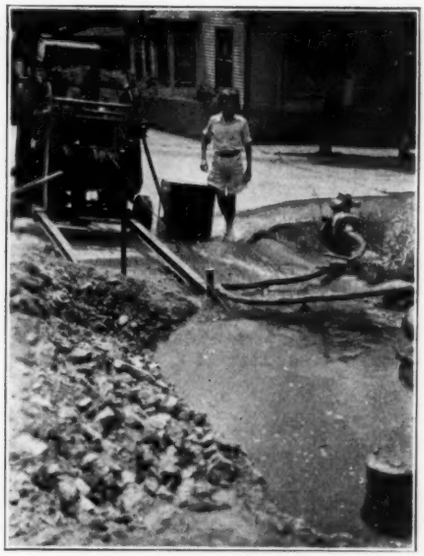
The "Carrier"

A rod with leather piston cups is used to thread cable through 4-in. and 6-in. mains.

blades are of spring steel. There are two flexible "pistons" from which the machine gets its drive. There are adjustable ports through the pistons, which we can set to control the volume of water passing the machine for sweeping the debris ahead and, at the same time, to prevent the machine from moving too rapidly. Closing the ports naturally gives added driving power for the tougher jobs. The pistons and cutting heads are on a flexible spring and cable type of shaft. Its flexibility will allow the machine to pass a standard 90° bend. Contrary to the belief of many, the machine does not take on any spiral or whirling motion in its travel.

Dollar Losing Debris

Some of the 1½ tons of solid material swept out of 3,976 ft. of 10-in. transmission main, to reduce pumping cost $2.37 per million. (See accompanying tables of data and costs.)



The Safety Winch

Pulling cleaning tool through a 4-in. line. In such operations the debris collects in the ditch, which is dewatered with the small portable pump alongside.

Cleaning 8 and 10 Inch Mains

The main is isolated and a section of pipe is removed at the point of beginning. This section should be long enough to give ample working room for inserting the machine. The machine is then jacked intothe pipe (see cut) and the pipe permanently jointed either by solid or Dresser sleeves. At that point at which we wish the machine to emerge the pipe is again cut. A short section is removed and bell and spigot fittings are used to rig a riser. Usually this is done with a 45° bend and a short piece of pipe. The joint need only be juted and chained. The purpose of the riser is to discharge the debris on top of the ground, rathre than in the trench. When the riser is rigged the pipe is all ready. The valve on the main is opened slowly to secure the proper amount of water and the machine begins to move. The machine generally moves about 100 feet per minute and it is possible to follow its travel through the line, as the water passing the pistons and the scraping blades is audible at the surface. Generally the water emerging from the riser will only be colored until the machine gets within about 300 feet, then the water is thick and black. The solid material may issue from the pipe like sausage, if the encrustation is marked. In the case of the 3900′ of 10″ line in South Charleston (W. Va.) there was an estimated one and one-half tons of solid material which came from the pipe. The machine will generally lodge in the riser pipe due to so much debris, and has to be helped out. When the machine has reached its destination (after only one trip through it: most cases) the riser is dismantled, the main flushed, jointed, and placed in service.

A Small Line "Make-Up"

In which the "carrier" with threading cable attached has been inserted in 4-in. main and is ready to travel.

Cleaning 4 and 6 Inch Mains

In the case of 6″ mains, where they are not so dirty, these may be cleaned by "pressure shots" as described for larger sizes of pipe. In one case where the pressure was low a booster pump was used to supply increased pressure for a 6″ "pressure shot." However, generally 6″ mains must be cleaned the same way as 4″ pipe, which I will now describe.

In cleaning 4″ mains the section to be cleaned is isolated and the main opened at both ends. At the beginning point a small cable is attached to a "carrier" and inserted into the line. The "carrier" is a short rod with leather pistons. The main is then jointed at this point with a portable coupling known as a "make-up." This "makeup" has a gland in the top through which the small cable may be fed. The water is then turned on behind and the water velocity takes the "carrier" and the small cable to the other end of the pipe. This small cable is then used to pull the big cable back to the point of machine insertion. The makeup is removed, the cleaning tool clamped to the large cable (see cut), the main permanently jointed, the water pressure turned on, and the cleaning tool is pulled through the pipe by a gasoline driven winch. This process is much slower than the pressure method and great care must be exercised to prevent breaking the cable and losing the machine. In this case a very slow speed is used. The winch automatically releases the clutch when the tension or pull becomes too great. This generally happens when the cleaning tool caught some joint lead or a bad obstruction. When the cleaning tool emerged the main was flushed and permanently jointed.

Obstacles Encountered

In pressure cleaning the drive of the machine is dependent upon the velocity of the water acting on the pistons, and in the event the machine encounters a cross increasing on the branches it will generally stop. In other words, in cleaning an 8″ pipe, if at an intersection an 8 x 10 inch cross is present the machine will hang. This is due to the pistons expanding and allowing the water to pass it instead of driving the machine.

If the wash water passing the machine is not sufficient to carry the debris ahead the machine will be fouled. We encountered one 8″ main in which the machine would move a short distance, then stop. After the wash water had moved the material ahead the

machine would move again. This happened on a long line where wash water was insufficient and blowoffs were too far apart. The machine had to re-run through this section and I am of the opinion that part of the debris was deposited behind the machine during the first cleaning.

Short radius bends with valves on one side caused several cuts to be made.

Insufficient pressure was a jinx on one job. We were cleaning a 10" main from the reservoir down the hill. The pressure at the point of beginning was only 17 pounds. Thus it was necessary to fill the line with water and bleed it rapidly at the bottom of the hill, thus creating a vacuum. When this was done it was then impossible to keep up with the machine.

Poor joints were responsible for a number of worries—poorly juted joints where the lead had run into the pipe. There were chunks of lead removed weighing 50-75 pounds, old pump gaskets, coil springs, timbers, rocks and, in one case a piece of 1½" pipe about 6 feet long. These had probably entered the system years ago when reservoirs were uncovered or when the pipe was laid.

An Ounce of Obstruction; A Pound of Cure

This section of 8-in. pipe didn't look "too bad," but results after cleaning showed that it was. Proof found in the accompanying tables of data, revealing the "before and after" story, is more convincing than many words about it.

Discoveries and By-Product Values

At Hinton practically the entire system was cleaned. As a result, the method in which tie-ins are made, the fittings, and location of mains were definitely established. I know that our superintendent there can now point out on the ground just what is at every intersection, because he made intersection cards accurately during the cleaning.

There were cases when a pipe which was supposed to be was not and vice versa. Old valves were found, some with box and all gone, some with stem broken and some found partly closed.

If anyone operating a water system, which has been in service for a number of years, attempts a job of main cleaning, he will probably be surprised at a great many things found. And, from the operating standpoint, the knowledge gained during cleaning of mains may well save a few nights sleep to the superintendent.

Conclusions

We feel that our main cleaning jobs have done a lot of good. Those who have seen the mains before and after know that flows have definitely been improved. Just how long this pipe will remain clean is another question, but we expect to keep a close check on the cleaned mains. In fact, we are taking daily samples at all points where we cleaned and are recording the pH, alkalinity and CO_2. Periodic flow tests will also be made to ascertain to what degree the main is tuberculating. We are trying to control our corrective-water treatments accordingly.

We do know that the fire flows have been greatly increased and that once weak hydrants are again gushing brisky. On transmission mains there have been definite and pleasing reductions in power consumed.

Costs and Cleaning Data

In the accompanying tables something of the data pertaining to cleaning operations and costs are presented for the benefit of those interested.

TABLE 1—Charleston Main Cleaning

Item	Pipe 6" Kanawha St.	Pipe 8" Va. St.	Pipe 10"** So. Chas.	Pipe 10"-8"** Nitro Line
Contract of Cleaning	$134.80	$271.70	$397.60	$1,488.95
Material Cost	6.19	48.86	138.29	250.40
Labor Cost	65.86	186.80	188.14	888.09
Total Cost	206.85	507.36	724.03	2,627.44
Number of Feet Cleaned	1348	2717	3976	29779
Cost per Foot	$ 0.1535	$ 0.187	$ 0.1823	$ 0.0834

* This cost does not include 8" temporary steel line which was laid. The rental of pipe, placing and removing cost $1,757.75 for 4200'. If this were added to the above the cost per foot for cleaning the 10" main would be $0.625.

** The 10" and 8" main is a transmission main and was cleaned as one unit. Therefore there was no breakdown in cost.

TABLE 2—Charleston Main Cleaning (Transmission Main)

Location	Size	Feet of Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
South Charleston	10"	3,976	66	130*
Nitro-Dunbar	10"	10,679	49	130
Nitro-Dunbar	8"	19,100	49	126
Charleston-Virginia St.	8"	2,717	—	138
Charleston-Kanawha St.	6"	1,348	—	115

* Yielding an estimated savings in pumping cost (power) of $2.37 per M.G. for the South Charleston main.

TABLE 3—Hinton Main Cleaning (Total Cleaning Costs)

Item	10" C.I.	8" C.I.	6" C.I.	4" C.I.
Contract of Cleaning	$177.40	$ 546.90	$255.60	$ 675.80
Labor Costs	42.92	238.33	185.60	376.86
Material Costs	44.25	245.54	189.30	301.96
Total Cleaning Cost	264.57	1,030.77	630.50	1,354.62
Cost per Foot	0.15	0.189	0.246	0.20

TABLE 4—Hinton Main Cleaning

Pipe Size	Ft. of Pipe Cleaned	No. of "Shots"	Max. Length "Shot"	Min. Length "Shot"	Ave. Length "Shot"	"C" Before Cleaning	"C" After Cleaning
10"	1,774	1	1,774'	1,774'	1,774'	—	128
8"	5,468	9	1,072'	215'	608'	48	126
6"	2,556	7	675'	189'	365'	80	117
4"	6,758	14	965'	36'	482'	44	122

TABLE 5—Sutton Main Cleaning

Item	Pipe 6" Main St.	Pipe 4" Town Hill	Pipe 4" South Side
Contract of Cleaning	$177.00	$325.40	$487.50
Material Cost	18.55	72.60	105.60
Labor Cost	90.50	166.40	249.20
Total Cost	285.85	564.40	842.30
Number of Feet Cleaned	1770	3254	4875
Cost per Foot	$ 0.161	$ 0.173	$ 0.172

TABLE 6—Sutton Main Cleaning

Location	Size	Ft. Pipe Cleaned	"C" Before Cleaning	"C" After Cleaning
Main Street	6"	1,770	42	136
Town Hill	4"	3,254	68	118
South Side	4"	4,875	71	117

THE NATIONAL WATER MAIN CLEANING COMPANY

Contractors for Cleaning of Water Mains

22nd Floor, 30 Church St., New York, N. Y.

BRANCHES

115 Peterboro St., Boston, Mass.
910 William-Oliver Bldg., Atlanta, Ga.
7103 Dale Ave., St. Louis, Mo.
208 East Forsyth St., Jacksonville, Fla.
3812 Castellar St., Omaha, Neb.
2587 Glen Echo Drive, Columbus, Ohio.
501 Howard St., San Francisco, Calif.
2028 Union Ave., Montreal, Can.

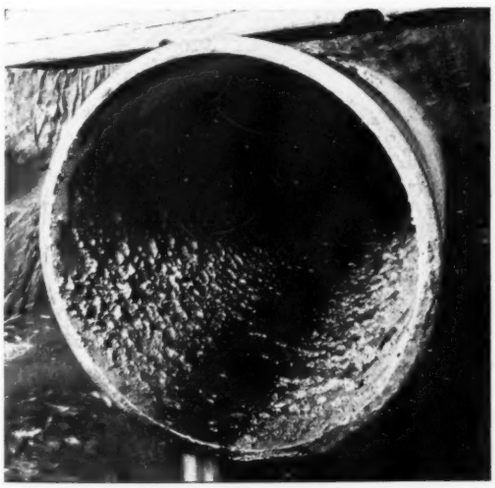
THE NATIONAL METHOD

WHAT IT IS

The National Method is a means of cleaning clogged water mains in order to restore their carrying capacity to normal. By using a water-propelled or cable-drawn machine, tubercles, incrustations and deposits are removed from the pipe lining.

Briefly, the method involves: cutting the pipe in two places, for entry and exit of the cleaning machine; inserting the machine; propelling it by water pressure or by cables through the pipe; placing a riser pipe at the exit, through which first the muddy water, and then the machine, emerge; finally, shutting off the water, removing the riser pipe, and reconnecting the main.

The total time required for shutoff of water in any district is five to seven hours. In an emergency, the pipe can be temporarily made up and service resumed. The work can be done at night if desired.



When a Pipe Lining Is Tuberculated to This Extent, the Frictional Resistance to Flow Is Considerable.

20" Main in a Midwest City Before Cleaning.

WHAT IT DOES

The National Method restores the carrying capacity of pipe to at least 95 per cent of that of new main. (This is our guarantee—the remaining 5 per cent being allowed for possible irregularities in laying—but usually, the main's capacity is restored to very nearly 100 per cent.)

The National Method gives you:

1. Greater delivery
2. Lower pumping costs
3. Reduced insurance rates
4. Clean water

The National Method has for more than thirty years been used in cleaning pipe for cities and towns, private water companies, railroads and industries, many of which have saved the cost of the cleaning job many times over, through savings in pumping costs, or elimination of the necessity for the purchase of new mains, or through having insurance rates lowered, or all three.

LET US CLEAN OUT YOUR CLOGGED MAINS

Not all pipe cleaning jobs are simple. We know how to meet and overcome difficulties that may arise. Don't take chances. Make it a NATIONAL job, and be certain.

Our records are at your disposal. A talk with one of our men places you under no obligation.

WATER REQUIREMENTS*

Volume Demand and Rates of Flow for Various Uses and Fixtures

Twenty gallons per capita daily is generally conceded to be the absolute minimum quantity of water needed to carry out, properly, the various functions of life of those served a supply of water piped into the property.

The basis for such a per user estimate is the following:

Drinking	1 gal.
Laundry	6 "
Bathing	5 "
Toilet (2 flushes)	5 "

(Possibly the item "Drinking" includes all water used in the kitchen. However, nothing is shown for scrubbing and other miscellaneous uses. So it is apparent that the average per user requirement should be at least 25 gallons and the *reasonable* minimum probably more nearly 30 gallons. In fact, surveys have revealed such to be the case.)

In a recent review of water consumption data the following procedure in estimating appears.*

"For purposes of estimating the probable use of water in a given building the engineer considers those quantities which are used for specific domestic operations and which do not vary appreciably with size of family, as well as the basic consumption rate of 20 gallons per capita per day. The total amount of water used in sprinkling a lawn does not vary with the number of persons living in a given house, nor does the quantity used for washing the family car. On the other hand, the use of water for personal bathing is directly related to the number of persons in the household.

"The figures which are presented here are subject to some variation but they may well serve as an index of the amounts which may reasonably be considered to be used in carrying out various domestic operations. Studies here and abroad have indicated that about one-half to two-thirds of the water used in ordinary household consumption is heated (bathing, laundering, dishwashing, etc.)."

Operation	*Quantity-of-Water*
Tub bath	25 gallons/bath
Shower bath	5 gallons/min.
Additional toilet flush/person	6 gallons/diem
Sprinkling lawn (⅝-inch hose)	7 gallons/min.
Washing automobile	150 gallons
Basic quantity/person	20 gallons/diem

"Two examples will illustrate the use of these data.

Example 1.—A family of five persons is to build a single house on a lot 50 by 100 ft. in a fairly good neighborhood. They plan to have a bathtub and do home laundering, but they have no automobile. How much water per capita (in round numbers) should be estimated as the daily consumption for this family

Basic figure $= 5 \times 20 = 100$ g.p.d.
Lawn watering = 20 min./diem for 3 mos. = 5 min./diem = 35 g.p.d.
Bathing—2 baths/week/person $= 5 \times 50/7 =$ 35 g.p.d.
Total = 170 g.p.d.
Per capita consumption = 34 g.p.d.

Example 2.—A family of three is to build a large house on a plot 125 by 250 ft. in an exclusive section of town. Laundering is to be done at home and the two cars probably will be washed twice a month at home. There is a shower for the head of the house, and two baths for the two women. What water consumption per capita could be estimated here?

Basic figure $= 3 \times 20 =$	60 g.p.d.
Additional toilet flushes, $3 \times 6 =$	18 g.p.d.
Lawn watering 1 hour/day for 4 mos. = 20 mins./day for the year =	140 g.p.d.
Bathing—2 baths/day =	50 g.p.d.
Showers—10 min./diem =	50 g.p.d.
Washing cars—600 gal./mo. =	20 g.p.d.
Total	326 g.p.d.
Per capita consumption	109 g.p.d.

Similar methods of approach may be used in solving problems involving large apartments and housing projects."—Jour. A.W.W.A.

In an analysis of available survey statistics from representative cities, essentially, the following conclusions appear in the same article.*

(1) The minimum domestic water requirements for an urban community or household should be assumed at not less than 30 gals./capita/day.

(2) For design of systems, service lines and interior piping it is safer practice in general to use a figure of 40 gals./capita/day.

(3) The increase in consumption can be estimated at a rate of 1% per year, until a maximum of 50 gals./capita/day is reached.

Water Requirements in Various Types of Housing

The following estimates of expected consumption in various types of housing are based on data presented in the same review.

Type of Housing	*Gal./Capita/Day*
Single Family Houses	
Minimum	35
Reasonable	55
Maximum	100+
2, 3 and 4 Family Houses	
Minimum	35
Average	40
Maximum	55
Apartment Houses	
Average	75
Maximum	100+
Housing Projects	
Minimum	35
Reasonable	45**
Maximum	90

RATES OF DRAFT PER FIXTURE OR USE

Individual Needs	Gallons per Day
For all household purposes, including kitchen, laundry, bath, etc.	30
Each cow	10
Each horse	10
Each hog	5
Each sheep	5
Continuous flowing drinking fountains	75

Lawn Fixtures	Gallons per Hour
½-inch hose with nozzle	200
¾-inch hose with nozzle	300
Lawn sprinkler	120
Park or golf course sprinkler covering a 106-ft. diameter area, with ¼-inch main nozzle operating at 50 lbs. nozzle pressure	990

Domestic Fixtures	Gallons
Filling the ordinary lavatory	1½
Filling the average bath tub	30
Flushing water cabinet closet	6
Shower bath	30

(*From, Peerless Pump Bulletin*)

*Based on data and computations in a review of water requirements in "Domestic Water Consumption" Jour. A.W.W.A., December, 1939—by M. A. Pond, and published information from various other sources.

**In measuring the proportion of total consumption that was used as heated water the average was 66%, or 28 gallons in the average total of 42 gallons used per head.

RATES OF FLOW FROM FIXTURES

Fixture	*Gallons per Minute†*		
	Fair	*Good*	*Excellent*
Bath Tubs	5	18	10
Showers (5" to 8" heads)	3	6	8
Lavatory Basins	3	5	8
Laundry Tubs	4	8	10
Sinks (Kitchen & Pantry)	4	8	10
Hose (Sprinkling & Washing)	5	8	10
Toilet Flush (Tank)	2	3	5
Toilet Flush (Flushometer)	20	30	40

†Copper and Brass Research Association figures, supported by other data.

Expected Consumption Rates and Requisite Pipe Sizes in Apartment Buildings

The following tables taken from a bulletin of the Bridgeport Brass Co. indicate expected reasonable rates of draft by apartments of various sizes and number of baths. Also is listed the minimum sizes of service lines and recommended sizes of riser pipes, based on a pressure loss of 10 lbs./100 ft. of run, and terminal fixtures pressure of 15 lbs./sq./in. during water use in all apartments on the same riser, from top floor to ground.

TABLE 1.

RATES OF USE AND WATER SUPPLY RISERS FOR APARTMENT HOUSES

(Based Upon 1-2 & 3 Baths per Ap't.)

One (1) Bath Apartment		Two (2) Bath Apartment		Three (3) Bath Apartment	
1 bath	15 gals.	2 baths	24 gals.	3 baths	30 gals.
1 W. C.	8 gals.	2 W. C.	14 gals.	3 W. C.	18 gals.
1 sink	4 gals.	1 sink	4 gals.	1 sink	4 gals.
1 lav.	4 gals.	2 lavs.	6 gals.	3 lavs.	9 gals.
	31 gals.		48 gals.		61 gals.
50% demand, 15 gals. per min.		40%, 20 gals. per min.		40%, 24 gals. per min.	

		RISER		RISER		RISER
Top Floor	15 gals.	1¼"	20 gals.	1¼"	24 gals.	1¼"
Next	28 gals.	1¼"	38 gals.	1½"	43 gals.	2"
Next	38 gals.	1½"	54 gals.	2"	64 gals.	2"
Next	51 gals.	2"	68 gals.	2"	82 gals.	2"
Next	60 gals.	2"	80 gals.	2"	96 gals.	2½"
Next	67 gals.	2"	90 gals.	2"	108 gals.	2½"
Next	71 gals.	2"	98 gals.	2½"	117 gals.	2½"
Next	78 gals.	2"	104 gals.	2½"	124 gals.	2½"
Next	81 gals.	2"	108 gals.	2½"	134 gals.	2½"
Next	83 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	84 gals.	2"	110 gals.	2½"	143 gals.	2½"
Next	86 gals.	2"	110 gals.	2½"	143 gals.	2½"

TABLE 2.

APARTMENT HOUSE SUPPLY SIZES OF SERVICE LINES FROM MAIN

(Based on Pressure Loss of 10 lbs./100 ft. Run)

For 4 and 5 Stories

No. of Baths	APARTMENTS PER FLOOR							
	Four		Six		Eight		Ten	
	Gals.	Main	Gals.	Main	Gals.	Main	Gals.	Main
1 bath	120	2½"	160	3"	200	3"	240	3"
2 baths	160	3"	200	3"	240	3"	280	3"
3 baths	200	3"	240	3"	280	3"	320	3½"

For 6, 7 and 8 Stories

No. of Baths	APARTMENTS PER FLOOR							
	Four		Six		Eight		Ten	
	Gals.	Main	Gals.	Main	Gals.	Main	Gals.	Main
1 bath	150	2½"	190	3"	230	3"	270	3"
2 baths	190	3"	230	3"	270	3"	310	3½"
3 bath	230	3"	270	3"	310	3½"	350	3½"

For 9, 10, 11 and 12 Stories

No. of Baths	APARTMENTS PER FLOOR							
	Four		Six		Eight		Ten	
	Gals.	Main	Gals.	Main	Gals.	Main	Gals.	Main
1 bath	200	3"	250	3"	300	3½"	350	3½"
2 baths	250	3"	300	3½"	350	3½"	400	3½"
3 baths	300	3½"	350	3½"	400	3½"	450	4"

DELIVERY THROUGH BRASS AND COPPER PIPES OF VARIOUS SIZES FOR VARIOUS PRESSURE DROPS

(Each line being 100 ft. long)

Pressure Drop	*Gallons per Min. Delivery Through*						
(Lbs.)	⅜"	½"	¾"	1"	1½"	2"	2½"
5	2	3	7	13	40	80	150
10	3	5	10	20	60	130	225
20	4	7	15	30	90	200	300
30	5	9	20	40	120	250	375

Blotting Out Waste

Safe Water
delivered night and day
Costs Less
than anything else you buy
· · but · ·
Don't Ignore Leaks!

Satisfied customers are worth more to us than revenue secured from water uselessly passing through meters.

INDIANAPOLIS WATER CO.

What Leaks May Cost

Size of Leak	*Gallons per 24 Hours*	*Gallons per Month*	*Cost per Month*
½"	47,600	1,451,800	$156.21
¼"	12,300	375,150	60.05
⅛"	3,200	97,600	19.65
1/16"	860	26,230	6.35
1/32"	215	6,550	1.97

(Above estimates are based on Indianapolis pressure without allowance for friction loss)

The above is a reproduction of the top side of a little blotter sent out to customers, reminding them of the high cost of allowing fixture leaks to persist. If as good at blotting waste as ink, the scheme is praiseworthy.

Incidentally, the Indianapolis Water Company gets in a good public-relations message about satisfied customers being worth more to them than the added revenue from the uselessly metered wastage.

WHAT LEAKS COST

SIZE OF OPENING	AIR		STEAM		WATER	
	Number of Cu. Ft. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 10c per M Cu. Ft.	Number of Lbs. Wasted per Month 100 Lbs. Pressure	Total Cost of Waste per Month @ 60c per M Lbs.	Number of Gallons Wasted per Month 40 Lbs. Pressure	Total Cost of Waste per Month @ 15½c per M Gals.
1" / 2	17,798,400	$1,779.84	805,000	$483.00	1,231,000	$192.00
3" / 8	9,979,200	997.92	460,000	276.00	692,400	108.00
1" / 4	4,449,600	444.96	203,000	121.80	307,700	48.00
1" / 8	1,114,560	111.46	50,500	30.30	76,900	12.00
1" / 16	278,640	27.86	12,750	7.65	19,200	3.00
1" / 32	69,552	6.96	3,175	1.91	4,800	0.80

Courtesy M. B. Skinner Co.

WATER METER TESTING PRINCIPLE AND PRACTICE

[*From "Testing Water Meters—Why and How"*]*

The testing of a water meter is very simple. It consists of checking the registration of the meter against the actual volume of water passing through the meter, as measured in an accurate volumetric tank or weighed on accurate scales.

Meter accuracy may be defined as the quotient obtained by dividing the meter reading by the actual volume of water. Thus a meter registering 9 gallons when 10 gallons are run through it has an accuracy of 9/10 or 90%. A meter registering 52 cubic feet on an actual volume of 50 cubic feet is 52/50, or 104% accurate.

Meter accuracy is commonly expressed in percentage fast or slow. Thus a meter which records 95 gallons when 100 gallons are run through it under-registers or is slow by 5%. A meter registering 102 gallons on the same volume would be 2% fast.

Good Practice in Testing

Before starting a test, water should be run through the meter or meters at a high rate, say 10 or 15 gallons per minute, until all the air is out of the meters and the line, and the delivery pipe to the tank is as full or as empty as it will be at the end of the test. Start the test flow with the test hand of the meter or meters on an even starting position or line on the dial. This can be done either by running water from the outlet of each meter until it has the test hand at the proper position, or the register can be turned around in the case until the test hand stands on the line.

When testing one meter at a time with calibrated tank or with scales having percentage beams, the test flow should be stopped when the meter has indicated the passage of the test amount. The percentage fast or slow of the meter can then be read direct from the tank gauge or from the percentage beam of the scales.

When testing several meters in series or when using scales or tanks without percentage markings, the flow should be stopped when the test volume of water has been run into the tank. The percentage fast or slow of the meter or meters can then be computed by dividing the meter readings by the actual amount of water. It will be seen that the computation will be much simplified if the amount of water is one, ten or one hundred gallons or cubic feet. Thus the divisor is one, which makes the meter reading direct in percentage of accuracy. Example: 100 gallons run through the meter; meter reading 96 gallons; meter accuracy 96%, or the meter is 4% slow.

Amount of Water for Tests

All test amounts except on lowest flow or "sensitive" tests should be at least enough to correspond to one complete revolution of the test hand on the meter dial. Often the test hand pinion is not in the center of the circle on the dial and this would introduce an error in reading with partial turns of the test hand. Common practice is to test on the small flows with an amount representing one revolution and on large flows with an amount representing ten revolutions of the test hand. On the other hand, it is possible to get an accurate test on a ⅝ inch meter with ten gallons or one cubic foot and many meter shops do not go beyond this. Of course the greater the amount of water the smaller would be the errors introduced by inaccuracies in readings.

Single or Series Testing

Meters can be tested one at a time or in series. When there are many meters to test there is a worth-while saving in water and time if several meters are tested at once. The number of meters in series or the number of units in the testing machine justified for any condition depend on the number of meters in the system and the frequency of testing. Testing machines or benches for up to 12 meters are in common use.

In series testing the flow can be stopped when the correct amount of water has been run through the meters into the tank, and the accuracy of each meter computed as indicated above. When only a few meters are tested in series it is possible to take advantage of the percentage calibration on the tank or scales by turning off the water when the fastest meter shows a registration of the test amount, reading the percentage accuracy of the meter, starting the flow again and stopping for each meter as it comes up to the desired reading. This method of obtaining the meter accuracy is not considered good practice as it involves changing the rate of flow for every start and stop involved.

Testing with Test Meters

For testing in the field the so-called test meter is convenient and satisfactory if only a rough check is desired. However, a test meter is only a meter and subject to the same variation in accuracy which is characteristic of all disc meters.

Further, a test meter is not positive in the same way as a tank or scales. Testing one meter with a test meter or with any other meter is simply comparing meters and is not recognized in many states which have regulations or laws applying to means or equipment for water meter testing. Field testing can be done much better and more accurately by means of a calibrated testing tank.

Money Value of Meter Accuracy

The accuracy of a water meter is a matter of dollars and cents to the customer and the utility.

Fortunately for the customers, water meters which were originally accurate cannot over-register beyond a slight speeding up in some water conditions. This action is self-limiting, for friction increases with the building up of the disc or piston and tends to counteract the speeding up. Water meters always slow down in service as they become worn, corroded or encrusted.

The intervals at which it is profitable to the water works to test meters and repair them depends entirely on the effects of the water and service conditions in making the meters under-register, on the value of the water taken but not registered, and on the cost of making the necessary tests and repairs. In other words, if the increased revenue from the meter pays a good return on the cost of making the meter accurate, it is simply *good business.*

Several states have recently adopted regulations which specify limits between meter tests in water utilities, both in time and

*A booklet distributed by Ford Meter Box Co., Wabash, Ind.

MFGR. NO. _____ CO. NO. _____ MAKE _____ SIZE _____

DATE PURCHASED _____ STYLE _____

INSTALLATION RECORD								TEST AND REPAIR RECORD								
INSTALLED		NAME	ADDRESS	Tap No.	Reasons for Removal	Removed		Date	Rate of Test			Repairs		Total Amt. of Water Passed Before Test	Tested By	REMARKS
Date	Reading					Date	Reading		Min. Flow	Inter. Flow	Max. Flow	Before Test	After Test			

Heading for a Suggested Form for Meter Record Card. This Can Be Adapted to Meet the Requirements of Any Meter Shop. Actual Size of Card Is 8½ by 11 inches.

in volume of water. These limits are necessarily broad, as the composition of water and its effect on meters varies widely in any state, and many utilities profitably test and repair more frequently than required. These regulations show the growing realization that meter testing *is* important.

The following table shows the value of water unregistered by meters of various percentages of slowness, with various amounts of water drawn through the meter and with water valued at from 10c to 50c per thousand gallons. These figures can be easily transposed into cubic ft. by recalling that 100 cubic ft. equals 750 gallons.

From the table it will be seen that with water at 10c per thousand gallons the return on the investment of testing and repairing a meter 4% slow will be only 40c with every 100,000 gallons of water drawn through the meter. It would take a large and active service to make frequent testing pay under these conditions.

On the other hand, with water at 50c per thousand gallons a meter failing to register 20% of the water passing through it (not terribly rare) would lose $1.00 for the water works with every 10,000 gallons. With these conditions maintained accuracy will pay a handsome return on the investment.

TABLE SHOWING VALUE OF WATER NOT REGISTERED BY METERS OF VARYING PERCENTAGES OF UNDER-REGISTRATION, WITH WATER FROM 10c TO 50c PER THOUSAND GALLONS, AND WITH THREE AMOUNTS OF TOTAL DRAFT.

	Value of Water Per 1,000 Gallons								
	@ 10c			@ 30c			@ 50c		
	Total Volume Drawn—Gallons x 1,000								
%*	10M	50M	100M	10M	50M	100M	10M	50M	100M
4	$ .04	$ .20	$ .40	$ .12	$ .60	$1.20	$ .20	$1.00	$2.00
6	.06	.30	.60	.18	.90	1.80	.30	1.50	3.00
8	.08	.40	.80	.24	1.20	2.40	.40	2.00	4.00
10	.10	.50	1.00	.30	1.50	3.00	.50	2.50	5.00
12	.12	.60	1.20	.36	1.80	3.60	.60	3.00	6.00
14	.14	.70	1.40	.42	2.10	4.20	.70	3.50	7.00
16	.16	.80	1.60	.48	2.40	4.80	.80	4.00	8.00
18	.18	.90	1.80	.54	2.70	5.40	.90	4.50	9.00
20	.20	1.00	2.00	.60	3.00	6.00	1.00	5.00	10.00

*Under-Registration Percent.

Steps in Testing a Water Meter

[A ⅝inch meter is used as an example. A larger meter would involve the same procedure but would require greater rates of flow.]

1. Insert Meter in Tester—Any means of connecting the meter water-tight in the test line is satisfactory but a regular tester is much more convenient.

2. Flush Meter Out With a Large Flow—This is to remove air from the meter and line. A flow of ten or more gallons per minute is desirable and should be continued until discharge indicates that all air is out of the line.

3. Bring Test Hand of Meter to a Mark—This can be done by stopping the water flow as the hand reaches the mark, or by turning the dial in the meter case if the meter bonnet is removed.

4. Run a Test at 10 to 15 G.P.M. Running 50 Gallons or 10 Cu. Ft.—It is desirable to run this much water although more would be just as good or better. Be sure the calibrated tank is empty or the scales balanced before the test flow is started.

5. Run a Test at 1 to 2 G.P.M. Running 10 Gallons or 1 Cu. Ft.—Here again the exact amount is subject to variation and more water can be run if there is plenty of time and water.

6. Run ¼ G.P.M. Test, Running at Least 5 Gallons or ½ Cu. Ft.—This low-flow test is important for reasons mentioned on pages 9 and 10.

7. Make a Record of the Tests—Put down in permanent form the accuracy of the meter at the three rates of flow, date of test and other pertinent information. See suggested record card on the previous page.

Renovating Water Meters

Water Companies, on the whole, and also several of the more progressive municipally owned Water Departments, have found that a little dressing up of overhauled meters before returning them to the customers' service has a desirable psychological effect on the customer. The spray gun and gilt or silver lacquer or a combination of the two is the most universally employed method of dressing up old meters after they have been overhauled and tagged "O.K." on the test bench.

Mr. La Verne Trentlage, Superintendent of Meters in the Water Department of Elgin, Ill., has evolved a scheme which goes the spray-gilting method one better in making "new" meters out of old ones. In the Elgin scheme the metal parts of the meter are given a treatment which removes the oxidized or carbonated coating from the metal and leaves the parts as metal-bright as when turned out by the manufacturer.

Cleaning and Brightening Procedure

(1) Dip meter parts for 10 minutes in *hot* Trisodium Phosphate solution (2½ lbs. or more of T.S.P. in 10 gallons of water).

(2) Remove meter parts from T.S.P. solution and rinse in *hot* water to remove the alkali.

(3) Dip the parts in Muriatic Acid solution (1 part 18 degree Muriatic Acid—to 2 parts of water). Allow to remain in this acid bath for approximately 15 minutes, or longer if necessary. Remove and rinse in hot water.

(4) To brighten to original lustre, immerse in the "bright-dip" solution (1 part 38 degree Nitric Acid, 1 part 66 degree Sulphuric Acid and 1 part water, plus a handful of common salt). Leave the parts in the bright dip for 5 to 10 seconds, the length of time depending on the composition of the metal and degree of brightness desired.

(5) Remove and rinse in *boiling* water to remove acid.

(6) To keep the parts from dulling on standing, a "stabilizing-dip" (especially prepared for this purpose) has been developed by General Chemical Company). After the rinse, the parts are dipped into this solution, removed and allowed to drain and dry.

Notes of Caution: Always add acids to water and *not* water to acids when making dilutions. This will preclude over-heating and spattering of the acid. Be careful to avoid splashing of the acid when dipping the meter parts. In case acid accidentally splashes on hands or face, wash at once in clean water to avoid an acid burn. Spattered acid is also hard on clothing and shoes. Rubber aprons and gloves are good protection.

Do not use iron or steel wire for dipping meter parts. Copper or monel metal wire is satisfactory.

STREAMLINE PIPE AND FITTINGS DIVISION MUELLER BRASS CO.

Port Huron, Michigan

STREAMLINE Copper Pipe and STREAMLINE Solder Fittings for Water Service Work

In 1924 the Mueller Brass Co. originated and were the first to introduce a product then known as Mueller Copper Service Pipe and Flared Fittings. This was a distinct innovation and was conceded to be the most revolutionary contribution of the time for water service purposes.

Waterworks' engineers and superintendents prefer as soft copper pipe as possible for water service work. STREAMLINE Type K Pipe is consistently and uniformly soft. It is made from Virgin Copper Ingot consisting of at least 99.94% copper and throughout every phase of its manufacture is under rigid and constant laboratory control. From the time we started to manufacture this product in 1924, and throughout the years since, we have produced the best and softest pipe that can be made for water service work.

RUST PROOF

STREAMLINE Copper Pipe is rust-proof and is superior to any other metal for service pipe work. Under normal conditions of soil and water, it will last for generations, and will deliver its full capacity of water free from foreign particles as clear and pure as it is in the water main.

FLEXIBLE

STREAMLINE Copper Service Pipe is exceptionally and uniformly flexible. It can be very quickly and easily bent around comparatively sharp radii without annealing or loading. It may easily be bent around obstructions encountered in the trench with a great deal less cost than would be entailed in removing the obstruction.

REASONABLE COST

Copper Pipe connected with STREAMLINE Fittings is very reasonable in cost, although naturally a little more expensive than rustable pipe. It really costs a great deal less over a period of time, because replacements are eliminated owing to the rust and clog-proof properties of STREAMLINE Type K Copper Pipe.

COUPLING
Copper to Copper

VIBRATION PROOF

STREAMLINE Copper Pipe connected with STREAMLINE Solder Fittings is free from the harmful effects of vibration. Vibration is not localized at the joints as it is with threaded or flared fittings, but is harmlessly dissipated throughout the service line.

PERMANENT

STREAMLINE Copper Service Pipe is permanent. Once installed it may practically be forgotten; it will give no future trouble. For years it will continue to give the same uninterrupted service and undiminished flow of water.

COUPLING
Copper to Iron

SETTLEMENT AND FROST ACTION

STREAMLINE Copper Service Pipe is so ductile that it will stretch enough to easily take care of any settlement of filled earth, or, in fact, anything that might impose a strain on the service line which would cause failure of rigid ferrous pipe or, at the very least, cause leakage at the threaded connections.

TEE

In the Northern States and in the Dominion of Canada, copper service pipe of our manufacture has an outstanding advantage that places it far in advance of any other service material. This advantage is its resistance to frost action. This service pipe containing water under almost any range of pressure used in water service work can be alternately frozen and thawed out for a considerable number of times without showing any effect except a slight increase in diameter.

STREAMLINE SOLDER FITTINGS

The STREAMLINE Solder Fitting is connected to the pipe by feeding solder through a feed hole in the fitting. Capillarity causes the solder to thoroughly bond the pipe to the fitting and produces an enormously strong joint. This joint is so strong that if, for instance, two ¾" sections of pipe are connected with a ¾" coupling and pulled in the Olsen Testing Machine, it requires approximately 9000 pounds per square inch before a failure occurs, and this failure is always in the pipe itself, and not in the joint. This is, of course, far beyond anything it would be required to stand under actual service.

ELBOW

COUPLING
Copper to Inside Thread

A copy of Catalog W-3, fully illustrating and describing these products, together with simple instructions for connecting, will be sent upon request.

STREAMLINE Fittings are manufactured under Patents 1,770,852, 1,776,502, 1,890,998.

COMPRESSED AIR FLUSHING OF SMALL MAINS*

By R. F. BROWN

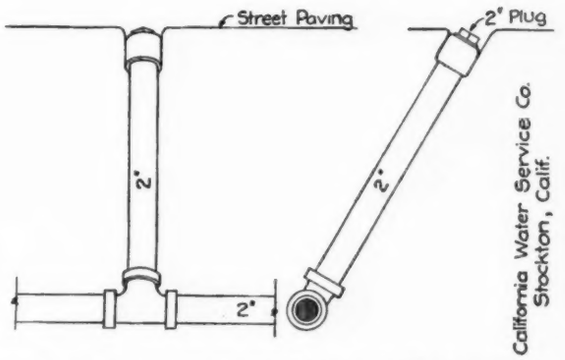
Plant Manager, California Water Service Co., Stockton, California

R. F. Brown

Many water systems in the older California towns, like Topsy, just grew without any suggestion of planning for the future. Stockton was no exception. As a consequence we found ourselves with a great many 2-inch lines in the thinly populated areas.

We have for many years followed the practice of flushing small mains and all dead ends regularly by opening fire hydrants and flusher valves and simply allowing the water to flow from the main under normal pressure of 45 pounds until the main is apparently clear. Under this program all dead ends and all small mains are given ordinary flushing, approximately at intervals of every two months.

This method, however, does nothing but freshen the water in the dead ends and small mains. In order to effect a more lasting cure for taste and odor complaints, we decided to try boosting the pressure in the main with air to attempt to break loose more of the troublesome algae and other deposited material that attaches to the pipe wall. All of our dead ends, regardless of size, and at least every other block of our 2-inch lines have what we call flusher-risers installed for the convenience of our periodical flushing program—see sketch.



RISER CONNECTION TO 2" MAIN FOR FLUSHING

Air Flushing Operations

Compressed air is put into the line through a service connection midway between two flusher-risers after we have first closed the shut-off valves on the intervening services. The valve on the flusher-riser is then opened. All water in the line is forced out through the riser, by air under 90 pounds pressure. As soon as the air has expelled all the water from the line it is shut off and water under our ordinary pressure is run through the line to sweep out, through the flusher-riser, all particles of scale, sand or foreign matter that have been loosened by the air "shooting." We proceed in this manner alternately turning into the line air under 90 pounds pressure and water at 45 pounds until the flushing water leaving the risers no longer carries with it any scale or other foreign matter.

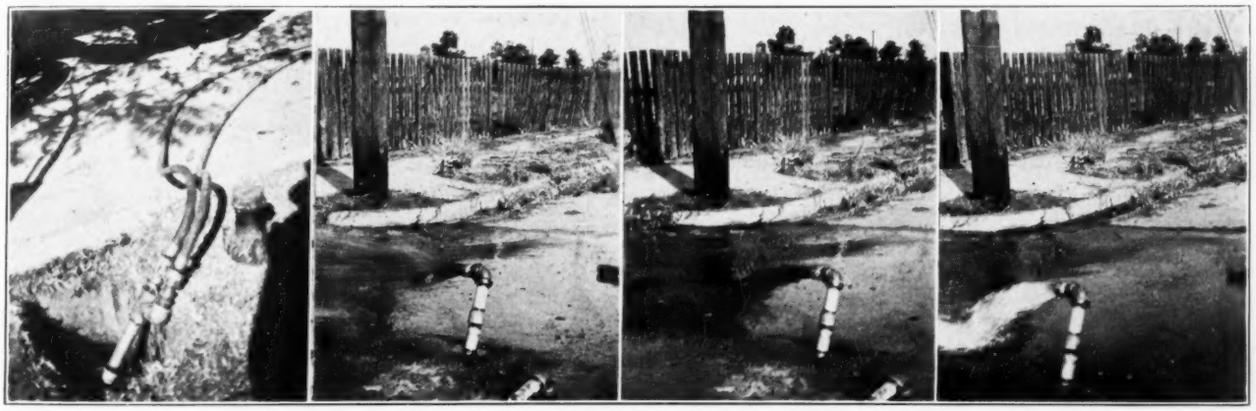
This system is apparently successful in accomplishing our purpose and it is economical, because the equipment required is only a portable air compressor and an air storage tank to provide a volume of air under pressure. No expensive cutting of mains or pavement is required and most jobs can be handled with a three-man crew.

When we first started this system we cleaned 40,000 feet of line, mostly 2-inch, over a period of two months. The cost was from 60 to 90 cts. per hundred feet, depending upon the number of services which had to be shut off and turned on again.

The success of this method of flushing is measured by the almost complete absence of the usual recurring taste and odor complaints from consumers served by mains thus treated. It is problematical how soon we will have to repeat this treatment, because from no consumer on the first line so treated has there yet developed a recurrence of complaints.

A secondary result, not anticipated, is the increase in carrying capacity of the 2-inch lines brought about by the loosening and blowing out of a great deal of scale. Thus has resulted a reduction in complaints of poor pressure as well as the taste and odor complaints.

A Self-Told Story



Air Lines Connected (This Time Through House Service at Curb Line)

First 90 Lb. Air Shot. (Note Extension Attached to Flushing-Riser)

First 45 Lb. Water Flush. (No Argument About Need to Eye or Nose)

Clear Water (Shooting and Flush Repeated As Indicated)

*From WATER WORKS AND SEWERAGE, April, 1937.

DE-WATERING MAINS WITH COMPRESSED AIR

Eliminates Pumping, Wet Trench, Loss of Time

By ARTHUR C. KING, Supt. Water Works
Taunton, Massachusetts

IN THE 1939 Reference Data Issue of "WATER WORKS AND SEWERAGE" an article by Roger W. Esty and Nelson Boardman of Danvers, Mass., describes the use of compressed air for removing water from mains.

Here in Taunton, Mass., we have adopted the method, developed by Esty and Boardman, and have successfully used it on pipe of such size that we believe our experience might be of interest to others who may have questioned the value of the scheme for mains of larger sizes. (See sketches on next page.)

An Experience with a 12-Inch Main

It became necessary to relocate about 600 feet of 12" cast iron main. Since occupied buildings were supplied from the section to be relocated, it was decided to lay the new main before cutting off the old for salvage.

After the new pipe was laid, the problem was that of making the connections between the old and new as quickly as possible, both on account of regular use and also the reduction in fire protection during the change-over. The section to be drained (about 2500 ft.), lay on an up-grade, as will be seen on the accompanying sketch (a), and hydrants were already in place at the high end and near the low end. The main was shut down, the hydrant near the low end was opened, and the air compressor connected to the hydrant *at the high end*. In a surprisingly short time, perhaps 40 minutes, although it was not timed, water ceased to come out of the hydrant and the main was cut. No water came out through the cut. The old and new sections were connected and the water turned into part of the new main within 4 hours, restoring service to all buildings. The upper end was then cut off and reconnected. Not a bit of ditch pumping was required.

We Try a 16-inch Main

Another large main de-watered with compressed air was of 16" cast iron. The length between gates was about 1200 feet—see sketch (b). About 800 feet was on a slight up-grade to a summit, where there was a hydrant. The other 400 feet was on a downgrade to the point of cutting, with a hydrant in that shut-down section just beyond the cut. The low hydrant was opened and the compressor connected to the hydrant at the summit. The water was quickly driven out and the cut made. In this case, apparently some gate was not shut quite tight as a trickle of water occasionally came out, but it was not enough to make trouble for us. We considered this job also a remarkable demonstration of the Danvers method.

On second thought, another hydrant might have been opened to de-water part of the main on the slope back from the summit away from the work, before the cut was made. Then the leakage would have accumulated back of the summit.

We Do a 20-inch Job

On another occasion we used the air to empty about 700 feet of 20" cast iron pipe, sketch (c). The upper end was nearly level for about 200 feet then the pipe sloped down from a hydrant at the summit about 500 feet past the work to be done to a hydrant at the low end. Here again no difficulty was experienced and the water was driven out very quickly, but was not timed.

We also drained about 1200 feet of 12" cast iron shown on sketch (d). In this case we cut out and replaced an 8" gate valve on a branch main a few feet away, and on an up-grade, from the 12" main. The whole job of de-watering, cutting out the old and inserting the new gate, was completed in less than 2 hours.

Our compressor is set for a maximum of 95 pounds pressure and starts up when the pressure drops about 10 pounds. We did not note what pressure was held during de-watering, but there was no indication of lack of air or pressure for these lengths of 12", 16" and 20" mains. The rated capacity of our compressor is 110 cubic feet per minute.

The scheme proved its worth very effectively.

IMPROVED METHOD OF MAKING WET TAPS*

By E. T. CRANCH
Manager, New Rochelle (N. Y.) Water Co.

It is assumed that all waterworks men are familiar with the ordinary hand operated machines for the making of wet-taps.

The hand operated machine, while a great convenience was, however, tedious to operate. A six or eight inch tap would take two or three hours to cut and the larger taps much longer. It would also take not less than three men, working in relays, to operate the machine successfully.

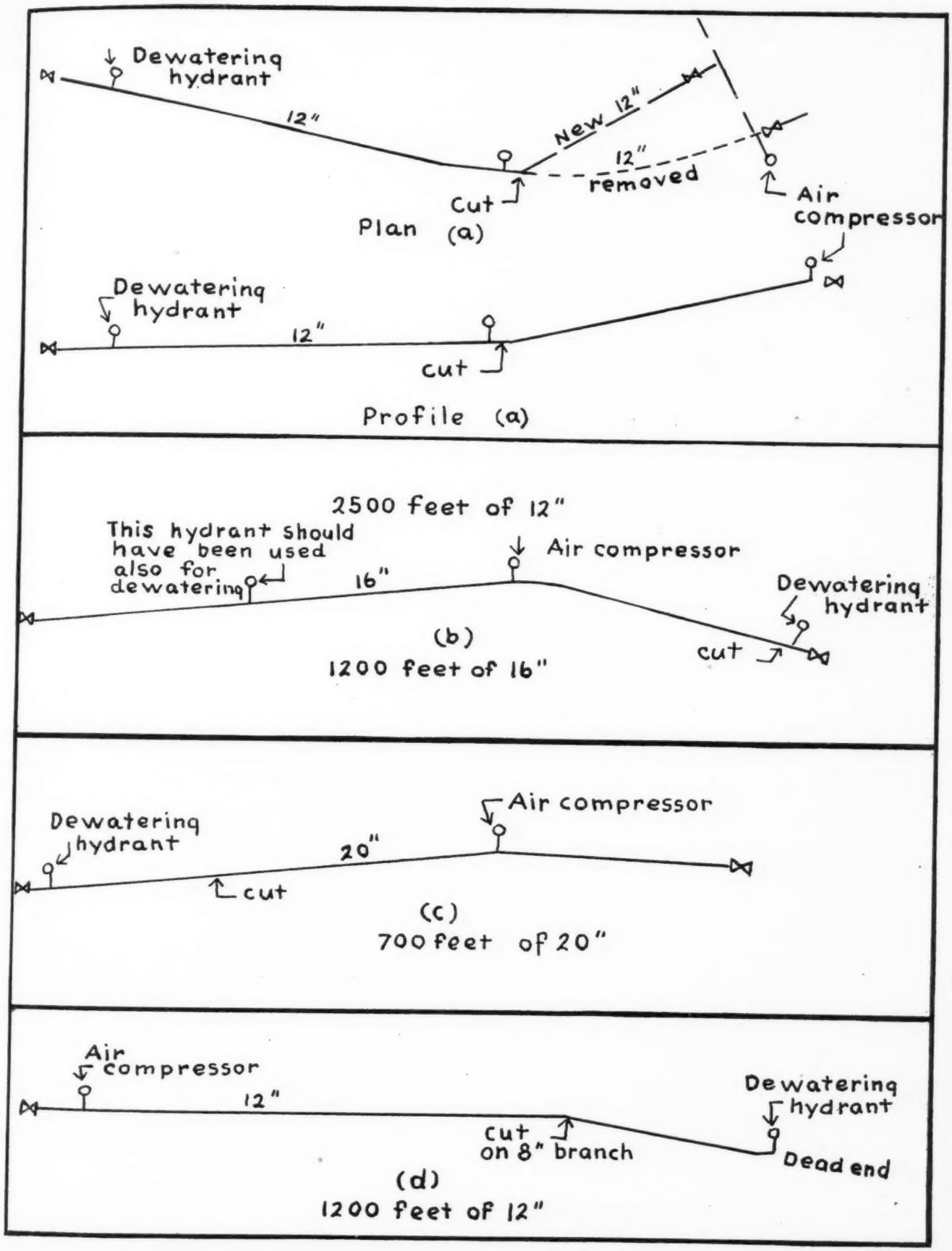
For plants which carry an air compressor unit in their equipment, there is now a means for making these taps quickly and easily. The old hand-type machine can be readily equipped with a bracket to permit the use of a compressed air motor and with a three-horse air motor an eight inch tap can be made in less than half an hour. With this arrangement it is also possible for one man to operate both the motor and the drill feed.

Equipping the machine with the motor-drive does not interfere with its continued use as a hand machine whenever conditions warrant, or should compressed air not be available at some time. It is only necessary to unscrew four stud bolts and remove the motor bracket. The machine is then ready for hand operation as before.

With the use of the air operated tapping machine we have recently made an 8-inch connection to a 12-inch main of class "B" pipe. In timing the whole operation it took just 90 minutes from the time the men started to place the sleeve on the pipe until the job was completed and the machine removed. The actual drilling time was, in this case, only 11 minutes.

The accompanying illustration is a picture made on an earlier job. The tapping machine, which is not new, was purchased some years ago from the A. P. Smith Mfg. Co. The compressed-air motor was supplied by Ingersoll-Rand Co.

DEWATERING MAINS



Sketches Revealing Conditions in Main-Dewatering Experiences Employing Compressed Air.

MAINTENANCE OF VALVES AND HYDRANTS

By CARL A. HECHMER*

Hyattsville, Md.

It is surprising, especially in small towns and villages, how little attention is given the maintenance of gate valves and fire hydrants on their water systems. The need of good engineering advice and design is recognized and is compulsory in almost every state. Practically every state health department has a law compelling the submission of plans for approval before a water system can be built. The question of good materials is also generally given the utmost consideration and the best valves and hydrants obtainable, in the judgment of those in charge, are purchased and put into the water system. In many instances they are promptly forgotten until an emergency arises and quick, sure operation is necessary. Unless valves and hydrants are given regular attention and properly maintained, the water works superintendent has no assurance that they will function properly. This fact applies to any make of valve or hydrant or to any other mechanical device or piece of machinery. Unfairly, the failure reflects on the designing engineer or the manufacturer of the material, and the local department is given a clean bill of health.

Valves

All valves on a water distribution system should be inspected once each year. This is the minimum requirement of the Fire Underwriters' Association. However, semi-annual inspection is advisable, if finances will allow it. Not only will the mechanical condition of the valve be assured, but valve boxes covered by paving material or earth will be located and reset ready for immediate operation in emergency. This is especially true in rural and suburban sections with a large percentage of unpaved streets. When a large leak occurs, excitement prevails and considerable time may be lost in locating a valve box. Occasionally a large stone or stones are found down in valve boxes and these conditions are revealed on inspection and removed. In case the valve has to be dug up, uncovering the valve, it is advisable to install new packing in the packing gland, which will prevent digging it up for repacking for a long time. Always repack a valve when it is uncovered for any repairs. Packing is cheap and easily installed while the valve is exposed. To dig up a valve just to stop a packing leak is an expensive operation. Inspection also locates valves which were carelessly or accidentally left closed. Any water distribution system is weakened by gate valves being closed when they should be open.

How a Valve Inspection Should Be Made

In addition to the box inspection, a valve inspection should proceed as follows: First set the valve key on the valve nut preparatory to turning the stem. Pour a small quantity of kerosene or diluted automobile crankcase drainings down the valve key stem. The oil will run down the key to the operating nut, thence to the valve stem and lubricate the valve stem against the packing gland. Finding its way into the packing gland, the packing will be softened and revived. Then operate the valve up and down several times, bringing the gate down into the groove hard each time and then opening the valve about one-quarter way. Valve troubles, preventing complete shutdown, are usually caused by the accumulation of sediment under the seat. Each time the gate is pushed down into the groove a small portion of this sediment is pushed out the sides. The high velocity of the water through the partly opened valve removes what is pushed out and the operation is repeated until the groove is sufficiently cleaned to allow the gate to seat properly. This procedure is especially recommended when valves fail to hold when attempting a shutdown. Of course, if the groove is filled with large stones or jointing material, the valve must be dug up and taken apart for repairs. The writer once operated a 16-inch valve up and down thirty times and secured a perfectly tight shutdown. The valve had not been operated for a long time, having been declared worn out, since it always allowed a large volume of water to pass with the gate turned down hard with levers on the key.

In operating the valve a check should be made of the number of turns on the stem. Generally, for the same size and make of valve, the number of turns to close or open the valve completely is the same, and a check can be made to see if the stem is bent, preventing the valve from completely closing or opening. Either condition should be corrected, as partly open valves weaken the system and, obviously, partly closed valves will not shut off the water.

If the valve stem can be turned around and around with no apparent effect on the gate, the stem is broken and must be repaired.

Geared valves, usually set in manholes, must be given special attention on inspection. The gears should be cleaned with a wire brush and greased with a light clinging grease. The stuffing box should, of course, be examined, and the by-pass valve should receive the same attention as the smaller valves on the distribution system.

Fire Hydrants

Proper care in the installation of a fire hydrant is necessary and makes maintenance less expensive. Proper drainage of the hydrant barrel after the main valve is closed is essential to prevent freezing of the hydrant in northern climates. The best method is to provide a bed of crushed stone or gravel around the bottom of the hydrant. The amount of stone necessary is dependent on the nature of the soil. In loose sandy soils a much smaller drainage bed can be provided than in a clay soil that absorbs water very slowly. A safe margin is to provide sufficient area to allow the drainage of an amount of water equal to twice the contents of the hydrant barrel. Connections are often made direct from the hydrant drain valve to the sewer. However, there are two serious objections, first, the cost and, second, the direct connection between a sewerage system and a domestic water supply, even though the possibility of contamination reaching the water in the mains is remote. Generally water mains are laid on one side of the street and sewers on the other. Hydrants are installed at the curb on the same side as the water mains to shorten the length of the lead. To connect each hydrant drain across the street to the sewer would prove much more expensive than providing a stone drainage bed.

Fire hydrants must be inspected at least twice each year, in the spring and fall. Four inspections annually should be made, if possible, and this number of inspections is advocated by the Fire Underwriters' Association. In high value districts, weekly inspections are often made during extremely cold weather. Arrangements should be made between the water department, the fire department and any other possible users of hydrants to report to the water department immediately after using a hydrant during freezing weather and an immediate inspection made to insure the good condition of the hydrant. Use of hydrants by private individuals or contractors should be allowed only by special permit, and the daily charge made high enough to permit daily inspection during freezing weather. During mild weather the inspection charge can be reduced, as weekly inspections are sufficient.

Valuable data may be secured by the fire hydrant inspection by measuring the static pressure, the residual pressure with one nozzle open, and the flow of water from the hydrant. [See artitcle on making hydrant flow tests (Wilson) elsewhere in this issue.—Ed.] Weak points on the distribution system can thus be determined and improvements due to new installation readily noted. System weakness due to unknown closed valves is also discovered and can be corrected.

Procedure for Making a Hydrant Inspection

The following procedure is suggested for making a hydrant inspection:

First make a physical examination of the hydrant, noting the condition of the operating nut, the nozzle caps and chains, and the general appearance of the hydrant. Then listen for leakage with an aquaphone placed on the operating nut. Then with the nozzle caps on tight open the hydrant valve. If static pressure readings are to be taken, replace one of the nozzle caps with one connected to a pressure gauge. Note if all the nozzles are tight in the hydrant and whether the drain valve has closed properly. If the drain valve has not closed, water will appear around the barrel of the hydrant on the outside. Then close the main hydrant valve and take off one of the nozzle caps. Observe the rate of drainage of the barrel to determine whether any obstruc-

*Engineer of Distribution, Washington Sanitary District.

tion has entered the drain valve. To clean the drain valve replace the nozzle cap and crack the main valve. As it requires about three full turns open on the main valve to completely close the drain valve on most makes of fire hydrants, the latter is still open on two turns. The full pressure of the water in the hydrant generally will push out any obstruction in the drain hole and the jet effect of the water through the hole will cut away the stone or earth which has packed around the outside. This simple remedy will eliminate the necessity of digging up the hydrant, in most cases, to correct drainage troubles.

With one nozzle cap off, open the hydrant and thoroughly flush out the water in the lead. At this time the observation of residual pressure and rate of flow should be made. Then close down the hydrant slowly. If the hydrant fails to close off entirely, the trouble is probably being caused by an obstruction under the main valve. Do not put extra leverage on the hydrant wrench, but open the hydrant up again and then close it, repeating the operation several times. Do not attempt to close down beyond the point where the obstruction prevents the main valve from seating properly, as the obstruction will become embedded in the main valve and connot be flushed off, or the valve seat will be damaged. Both valve and valve seat are damaged by attempts to force closing against obstructions. Foreign matter can generally be dislodged by flushing and it is then not necessary to dismantle the hydrant.

After the hydrant is closed and the rate of drainage checked, the stem should be oiled and the nozzles greased with a graphite grease. This kind of grease will not wash off and it prevents the nozzle caps from sticking.

Inspection Records

Record of the inspection should be kept on a field sheet. The location of the hydrants to be inspected can be entered on the sheet in the office. These will allow correct routing and prevent skipping any hydrants. The information on the field inspection sheets can then be transferred to a permanent record card in the office. A card should be in the file for each hydrant, stating the size, make of hydrant, and information regarding pressure at the hydrant. The date of each inspection should be entered on the card together with the observed pressures and rate of flow. Necessary repairs and their costs can also be recorded on the card and a history of each individual hydrant is easily obtained.

For quick reference the following is suggested: Use a map of the water system mounted on wall board with a push pin to denote the location of each hydrant. The color of the pin can show the condition of the hydrant as reported daily by the hydrant inspectors and the repair foreman. Use a blue pin for a hydrant in good condition, a black pin for a hydrant in need of minor repairs but not out of service, and a red pin for a hydrant out of service. Then when an inspector reports a hydrant out of service it is possible to tell at a glance whether the hydrants around it are in good condition. If several makes of hydrants are in use, it is an advantage to know the make of hydrant before sending out a repair gang so the proper parts can be carried along. By using a small round colored disc under each push pin it is possible to determine at a glance the make of each hydrant, a different color being used for each make of hydrant.

NORTHROP & COMPANY, Inc.

50 CHURCH STREET — NEW YORK, N. Y.

THE "FLOW-OM-ETER"

● A low cost impeller type meter for fire lines. Installed through 2-inch tap.

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● Self-priming centrifugal pumps from the 61 lb. light weight unit to heavy duty 10-inch giants. Also Marlow diaphragm lift and force and diaphragm open pumps. Portable floodlighting generator sets.

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PRODUCTS:

Simplex Venturi Type Meters for Measurement of Water, Sewage, Sewage-Sludge, and Air; Filter Rate of Flow Controllers; Loss of Head and Rate of Flo Gauges; Simplex Pump Casing Tap Meters; Pilot Tubes and Manometers; Portable Pitot Recorders; Water Level Gauges; Air Release and Air and Vacuum Valves; Proportional Chemical Feeding Devices; Sewage Aerators; Rotary Distributors; Hydraulic Equipment of Special Design; Sand Expansion Indicators, Summators, Air Differential Meters, Simplex Gyrometers.

SIMPLEX METER REGISTERS:

Primarily designed for use with Venturi tubes, Simplex meter registers are also used with Simplex pitot rods, orifice plates, and pump casing taps, as primary actuating devices. They are designed for use in measuring liquors and gases under all pressure conditions and are particularly fitted for the measurement of raw water, wash water, filtered water, raw sewage, screened sewage, mixed liquor, raw sludge, digested sludge, and air.

Noted for their ability to operate under small Venturi heads, Simplex meter registers measure accurately flows corresponding to water differentials of from ⅛" and up. Particularly designed to measure accurately the slightest change in rate of discharge, Simplex meters can be furnished to either indicate, record, or totalize the flow, or in any combination of these functions. Simplex meter registers of standard form are also furnished for the measurement of discharge through egg-shaped flumes, Parschall Venturi flumes, weirs, and other forms of primary devices wherein a free-falling discharge is present as well as for use with Simplex Pump Casing Taps.

Simplex meter registers can be arranged for mechanical totalization of the flow from any number of individual instruments whereby the total flow can be transmitted to either a large dial indicator, a total flow recorder, or a complete summation meter of the indicating, recording, and totalizing type.

Simplex meter registers can be operated by air differentials, thereby preventing the entrance of any sewage, sludge, or corrosive liquors into the meter float cylinder.

Each instrument has included with it as a standard item of equipment a device whereby its accuracy and sensitivity can be checked at any time during its period of service. Newly developed meters include the Simplex Impact Flume and Meter which enables accurate measurement of free discharging fluids by transforming the energy gradient into terms of rate of flow.

The Simplex Gyrometer is a differential pressure operated totalizing instrument designed for wall or panel mounting and adapted to the measurement of both liquids and gases.

SIMPLEX FILTER RATE OF FLOW CONTROLLERS:

Provide an efficient device for the operation of gravity or pressure filters which maintain the rate of discharge through the bed at a constant, regardless of variations in pressure or water level,

utilizing as an operating means only the pressure effect of the water flowing through the filter effluent line.

Simplex Controllers operate with the lowest obtainable head losses when wide open; attain the highest degree of accuracy in control without the use of compensating mechanisms; and are capable of covering the largest possible ratio from maximum to minimum rates with any given size of unit; avoid the use of any electrical mechanisms in their operation; start quickly from a wide open position, and take the rate for which set in less than fifteen seconds.

The Simplex, direct-acting controller is arranged for either straight-through, right, or left-hand outlet as may be desired, and can be installed in either a vertical or horizontal line, as required.

Simplex rate of flow controllers can be equipped with the Simplex master control system, whereby the rate through the entire battery of filter units can be changed from a single point on the operating floor or wherein the rate through each controller unit will vary with the elevation of water on the filter or in the clearwell.

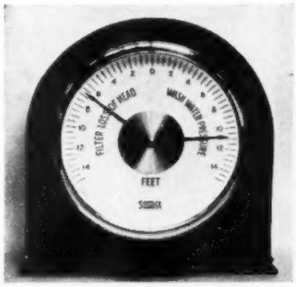
Simplex rate controllers can also be arranged with means for changing the rate from the operating floor.

SIMPLEX FILTER GAUGES:

These may be furnished in any combinations of indicating, recording, and totalizing rate of flow with indicating and recording of lost head, wash water rate or sand expansion.

Simplex gauges are of the mercury float operated type, wherein the Simplex bell-shaped float is used to provide uniform graduations of flow on both indicating dial and recording chart.

Similar in design to the Simplex meter register, Simplex filter gauges respond to the slightest variations in rate or loss, and will measure accurately over the entire range with an average error not exceeding ± 3%.



Simplex rate of flow gauges have been arranged for totalization, wherein there is shown on a single 24" diameter dial gauge, located on the operating floor, the total flow through any or all of the controller units. There can be mechanically linked to the total flow indicator, chemical feeders or chlorinators, thereby providing accurate control of the chemical dosage at all time during the plant run.

Simplex Sand Expansion Indicators and Recorders provide a means whereby filter efficiency can be increased and wash water costs reduced. They are available for installation on existing filter units as well as on new plants.

Also available for measuring the depth of water in clear wells, wash water tanks, sedimentation basins, are Simplex water float operated gauges, which can also be furnished in any combination of the indicating and recording types.

Simplex gauges are accurate, dependable, and easily intsalled—a high-grade quality product, made with precision and care.

SIMPLEX AIR RELEASE AND AIR AND VACUUM VALVES:

In the design and operation of large steel pipe lines flowing under gravity, consideration should be given to the possibility of collapse, in case, for any reason, the internal pressure is reduced below that of atmosphere.

Simplex Air and Vacuum Valves are used on large mains, where there is danger of collapse, due to vacuum; the valve breaking the vacuum, thus preventing collapse. They facilitate the filling of the main, since wide open until full of water.

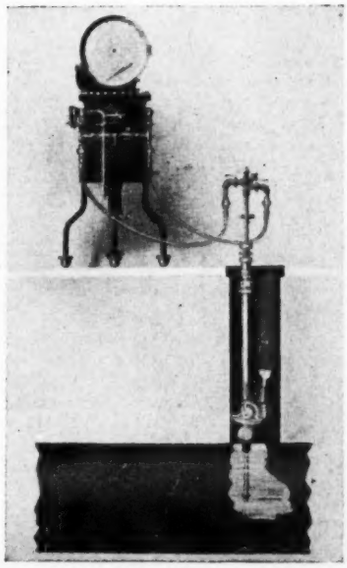
Simplex Automatic Air Release Valves have been designed to release, automatically, accumulations of air. They possess the merits of continuous operation without attention; simplicity; compactness; accessibility, and low cost, all of which are proved by over fifteen years' satisfaction to many users. Located on the high portions of the line, they insure automatic venting of the line and a continuous flow.

SIMPLEX TUBE RECORDERS:

For use with Simplex Round or Flat Pitot Rods —afford not only a record of velocity but can be furnished with pressure elements to give simultaneous readings of velocity and pressure.

This equipment may also be used for Water Waste Surveys or for conducting water flow investigations.

Indispensable to water works engineers for determining character of the flow in the mains of the distribution system.



TREATING WATER TO PREVENT CORROSION*

By JOHN R. BAYLIS†

Associate Editor, Waterworks & Sewerage

The writer, in 1930, presented some of the factors involved in preventing corrosion of water pipes.[1] Curves were given to show the solubility equilibrium of iron and zinc compounds in the presence of their respective metals. These curves (Fig. 1) show that practically no iron or zinc will exist in solution when the pH is above 8.0. At a pH of 7.0 several parts per million of either metal may exist in solution in some form in the absence of oxygen, and at a pH of 6.5 quite a large amount of iron or zinc may be found in solution in the absence of oxygen. The article explained how corroding iron took all the free CO_2 and much of the half-bound CO_3 from the water, leaving the water distinctly alkaline where there was no dissolved oxygen present. If the water contained dissolved oxygen the iron was precipitated as a hydrous oxide. Section of a 1-in. cement lined pipe, which had been in service for 50 years at Danvers, Mass., also was shown. The interior of the pipe was in fairly good condition, indicating that the lining was still giving very good protection.

Carrying Capacity of Pipes Greatly Reduced by Incrustation Resulting from Corrosion.—That the carrying capacity of iron pipes may be greatly reduced by tuberculation and incrustation as a result of corrosion is well known to most every one.

Haydock[2] describes how cleaning the tubercles or incrustation from several pipe lines increased the flow. One line carried only about one-half its theoretical capacity, and another about two-thirds. Cleaning a pipe line 3 miles long increased the capacity to the extent that a pumping station could be abandoned, and cleaning another line 5 miles long also enabled the abandonment of a pumping station. The friction loss through a 12-in. line 4 miles long 20 years old was nearly three times that of a new line. The capacity was increased by approximately 35 per cent and the delivered pressure by 20 lb. The gravity delivery of a 16-in. pipe 10.5 miles long was increased 60 per cent by cleaning. Cleaning a 13 mile section of a 12-in. pipe line 22 miles long, which had been in service about 16 years, increased the capacity approximately 35 per cent, and cleaning another section of the line 6 miles in length increased the carrying capacity to 46 per cent.

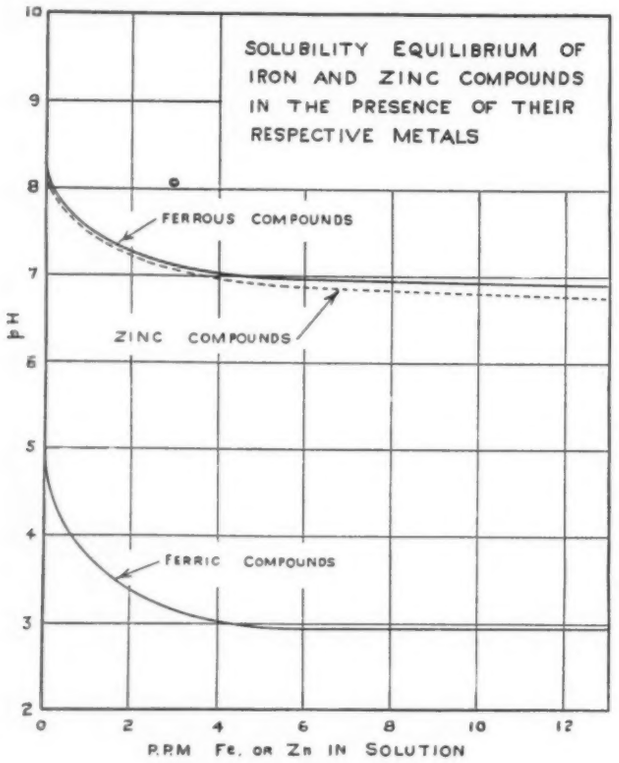

SOLUBILITY EQUILIBRIUM OF IRON AND ZINC COMPOUNDS IN THE PRESENCE OF THEIR RESPECTIVE METALS
FERROUS COMPOUNDS
ZINC COMPOUNDS
FERRIC COMPOUNDS
pH
P.P.M. Fe. OR Zn IN SOLUTION

Fig. 1

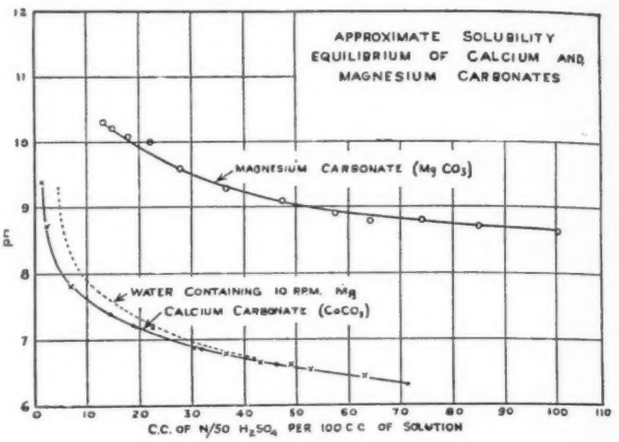

APPROXIMATE SOLUBILITY EQUILIBRIUM OF CALCIUM AND MAGNESIUM CARBONATES
MAGNESIUM CARBONATE ($MgCO_3$)
WATER CONTAINING 10 P.P.M. Mg
CALCIUM CARBONATE ($CaCO_3$)
pH
C.C. OF N/50 H_2SO_4 PER 100 C.C. OF SOLUTION

Fig. 2

Increased Pumping Pressure or Larger Mains Very Expensive.—In some instances it is possible to deliver the desired amount of water through distribution systems that have become partially clogged by increasing the pumping pressure as the friction losses increase, or to install booster pumping stations on the distribution system in certain sections where the pressure is low. Haydock refers to the delivered pressure being increased 20 lb. by cleaning the pipes in one instance. Assume that it was desired to maintain this 20 lb. increased pressure, evidently it was quite expensive to do it at the pumping station. A fair average of the cost of lifting one million gallons of water 1 ft. in height is probably 5 ct. Twenty pounds is equivalent to about 46 ft. in head. In this case it would cost about $2.30 per million gallons to maintain the increased pressure.

If corrosion is going to reduce the carrying capacity of the water mains in a certain city 50 per cent within 20 years, what is the best way of handling such a situation? Should mains be installed large enough to give the desired capacity with a 50 per cent reduction in carrying capacity? The cost of such an investment over what would be necessary if there was no corrosion very likely would be much more than the cost of making the water reasonably non-corrosive.

With the exception of feeder mains, engineers usually design the water distribution system for fire protection. How many engineers allow for a 50 per cent reduction in the carrying capacity of the pipes within 20 years where the water is corrosive? How many make any distinction whatever in the design where the water is corrosive and where it is not corrosive? The writer is of the opinion that corrosion has not been given its proper consideration in the design of water systems. This is largely due to the lack of specific information in the past as to how much the carrying capacity will be reduced within a certain time.

Treatment with an Alkali for Partial Protection.—The literature on the treatment of water to prevent corrosion indicates quite conclusively that the corrosiveness of water may be greatly reduced by proper treatment. It seems that some of the authors of articles on corrosion prevention do not fully realize the importance of a film for protection. So long as iron stains are prevented, some think that this is all the treatment that is necessary. As a matter of fact the carrying capacity of the pipes may be reduced just as rapidly as before, because most of the corroding iron is deposited near where the corrosion is taking place and forms large tubercles that are more effective in reducing the carrying capacity of the pipes than if the rust was

*Excerpts from an article which appeared in WATERWORKS AND SEWERAGE.

†Physical Chemist, Bureau of Engineering, Chicago, Ill.

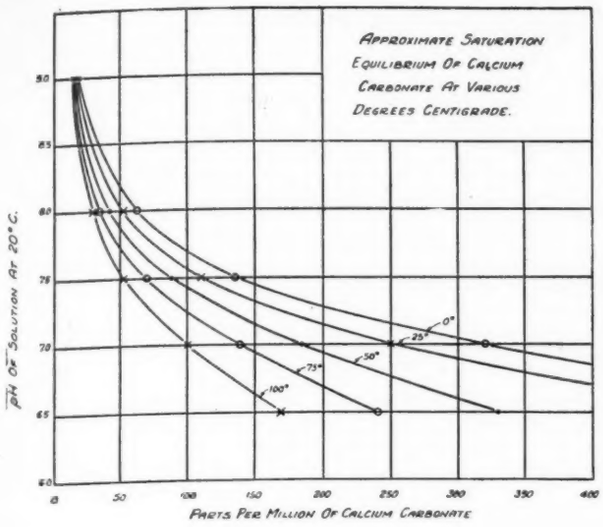


Fig. 3

deposited fairly uniform over the surface of the pipe. Treatment just to the point where red water complaints cease may not materially reduce the cost to the water department for cleaning pipes, constructing new mains, and increasing the pumping pressure.

Water Just Saturated with Calcium Carbonate s the Most Desirable Equilibrium.—As a general rule, it might be said that water saturated with calcium carbonate is the most desirable equilibrium when everything is taken into consideration. This is not strictly true for very soft waters, for it is desirable to have the water slightly supersaturated part of the time so as to form a thin protective film. Where the calcium carbonate alkalinity of the water is below 30 parts per million the application of lime to produce a slight supersaturation of calcium carbonate should be done with considerable care, otherwise caustic water might be produced. After a thin coating has been formed on the pipes the water should be kept saturated with calcium carbonate practically all the time to keep the coating from being dissolved. It is admitted that the very soft waters are the most difficult to protect, for we are working with equilibriums difficult to maintain exactly on the saturation point. It may be almost impossible to do this with the force available in small plants and it may be necessary to sacrifice some protection to avoid occasional caustic taste in the water. There is no reason why large plants with skilled supervision should not be able to maintain a fairly constant equilibrium.

Table I—Rapid Increase in pH Caused by Corroding Iron

Alkalinity	Time in Contact with the Iron Minutes	pH	Fe in Solution
39	0	7.2	
	1	7.3	
	2	7.4	
	3	7.7	
	5	8.2	
	10	9.2	
	15	9.4	
35	20	9.6	0.0tr

Where water has a calcium carbonate alkalinity in excess of about 30 it is easier to protect the pipes. If this water is placed in contact with an iron surface the iron going into solution will take up all the free Co_2 that is in the water and part of the half-bound CO_2. Table I shows how quickly the pH changes in water exposed to iron lathe turnings. After the pH reaches 8.1 no free CO_2 is present. This was due to the CO_2 combining with the corroding iron.

At any point on the surface of an iron pipe where corrosion starts to take place due to the surface becoming exposed in some manner, there is a tendency for the iron going into solution to take up the free and part of the half-bound CO_2, producing a supersaturation of calcium carbonate in the immediate point where corrosion is taking place. This supersaturation helps to quickly form a coating over the exposed surface both by precipitating the iron compounds and also some calcium carbonate, especially when the water has a fairly high alkalinity. If the water in the mains is saturated with calcium carbonate, then the precipitated calcium carbonate will not be dissolved out of the percipitate. It will remain where it is precipitated to offer protection against further corrosion.

Most natural waters contain magnesium carbonate as well as calcium, and the presence of a considerable amount of magnesium may materially alter the equilibrium curve. This is shown by the curves in Fig. 2. The presence of sodium carbonate also alters the curve. When sodium carbonate is present the only way the saturation equilibrium of the water in regards to calcium carbonate can be determined is by actual trial.

Temperature also has an effect upon the saturation equilibrium of calcium carbonate. The curves shown in Fig. 2 were determined at room temperature, that is, about 20 to 22° C. The other curves are based on actual tests, but not enough were run to state that the curves are absolutely correct. They should be regarded as somewhere near the true lines.

Corrosion prevention by treatment of the water has been demonstrated to be practical and economical. This being true, then it seems that all corrosive waters should be treated.

[1]Baylis, J. R. How to Avoid Loss by Pipe Corrosion. Water Works Engineering, 83:13-14, 31-32, 35-36, Jan. 1, 1930.

[2]Haydock, C. The Cleaning of Cast Iron Water Pipe Lines. Jour. Am. Water Works Assoc., 11:533-4, May, 1924.

The Influence of Dissolved Oxygen on Corrosion Losses

Engineers and chemists are constantly studying the theories and mechanics of corrosion because it is only through better understanding of fundamentals that they will be able to diminish losses due to corrosion.

Thirty years ago, R. W. Whitney, now vice-president of the general Electric Company, announced that the corrosion of metals was an electrochemical process and this view is now generally accepted. When a metal is in contact with even slightly acidic solutions, corrosion takes place by the chemical process of the metal replacing the hydrogen in the acid. The acid dissolves the metal and thereby hydrogen is released. The same holds for corrosive waters.

Released hydrogen coats the metal surface with an electrically charged layer that prevents the chemical reaction from continuing at the initial rate. If the hydrogen layer is built up to a sufficient thickness the reaction is practically stopped. However, under natural conditions, the hydrogen combines with the oxygen of the air or that dissolved in the water to form water and solution of the metal goes on. The *amount of oxygen* available to remove the protective hydrogen blanket determines the extent of corrosion.

Impure metals are corroded more quickly as a rule than pure metals. Electrochemists believe that this is due to the impurities taking up the oxygen. Contrary to the popular belief, however, pure metals are subject to corrosion under the action of certain acid solutions. Prof. O. P. Watts of the University of Wisconsin has recently shown that if oxygen is absolutely excluded copper will not corrode in a solution of sulfuric acid, a reaction that is very rapid in the open.

The importance of the dissolved oxygen content of corrosive water is thereby once more emphasized. When this element is present in high concentration a higher pH value must be maintained to prevent corrosion of mains than otherwise; and, particularly of household services or piping subjected to increased temperatures which create accelerated attack.

This suggests that there is some question as to the merits of aeration of waters which are normally aggressive, unless the pH value is raised sufficiently by alkali addition to reduce the hydrogen ion concentration considerably; below that which is commonly considered to represent a neutral water. It has in fact been demonstrated that ofttimes waters high in oxygen content and low in hardness must be raised to pH 9.5 in order to check even the cold water corrosion of mains. In some aerated waters a pH value of 10 to 10.5 is required, which is costly and questionable practice with public supplies.

CONTINUOUS STABILITY AND CORROSIVITY INDICATOR

By LINN H. ENSLOW, Editor
Water Works and Sewerage

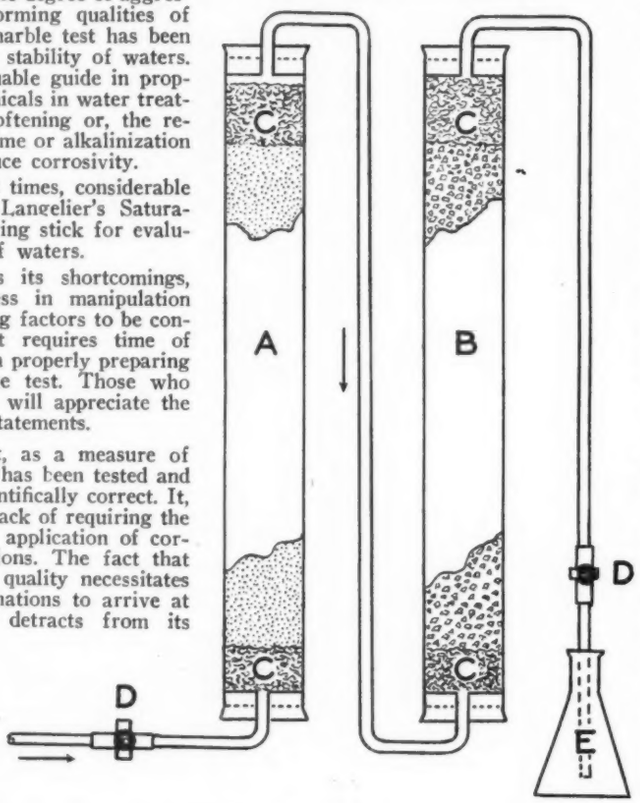
The so-called Marble-test has been employed for some years as a laboratory procedure in determining the degree of aggressivity, or the scale forming qualities of waters. In short, the marble test has been employed to reveal the stability of waters. It has served as a valuable guide in properly proportioning chemicals in water treatment—whether it be softening or, the reverse, hardening with lime or alkalinization by other means to reduce corrosivity.

Now, in more recent times, considerable has been heard about Langelier's Saturation Index as a measuring stick for evaluating the corrosivity of waters.

The Marble-test has its shortcomings, requires some exactness in manipulation and there are influencing factors to be considered. In addition it requires time of chemists or operators in properly preparing for and conducting the test. Those who have employed the test will appreciate the significance of these statements.

The Langelier Index, as a measure of stability or corrosivity, has been tested and demonstrated to be scientifically correct. It, however, has the drawback of requiring the services of an analyst, application of corrections, and computations. The fact that changes in raw water quality necessitates new analytical determinations to arrive at the Saturation Index detracts from its value as a practical method in day to day anti-corrosion treatment.

With the thought in mind of simplifying the marble-test, making it dependable and non-time consuming, and at one operation revealing the Stability Index by making but two simple pH determinations, or two simple alkalinity titrations, the device illustrated in the accompanying sketch suggested itself as a continuous stability indicator.



It is immediately apparent that with this contact device, in continuous service, the chemist or operator will find a prepared sample of marble-treated water awaiting his arrival at the plant, day or night. And, without doing anything about it, another will be ready at any time to reveal the effectiveness of altered chemical dosages.

Parts Involved

"The "Continuous Stability Indicator," as it has been christened, is simple to construct. It consists of the following parts:

A—Glass or metal tube filled with finely ground limestone, marble or chalk.

B—Twin tube filled with marble or limestone chips, or coarse silica sand. (This tube functions as a trap for swept over chalk powder. Also colloidized chalk, if any, will plate out on the grains.)

C—Plugs of compacted glass-wool, or other suitable supporting and straining material.

D—Stop-cocks or pinch-cocks, for regulating flow rate, and in disconnecting apparatus, etc.

E—Flask or bottle, slowly but continuously overflowing with carbonate saturated water. (From this reservoir portions are drawn for comparison with influent water, in respect to pH value and/or total alkalinity.)

Test Procedure

Two samples of water are taken. Namely, some of that from the pipe line feeding the device and some of the effluent water collected in the flask or bottle.

A simple titration of these "before and after" samples for total alkalinity will reveal whether the treated water from the plant (or any unit of it) is a marble dissolving (corrosive) water, or is a carbonate depositing (scale forming) water, and to what extent.

If it be desired to determine the Saturation Index for record, or use as a control check, a simple pH determination on the "before and after" samples yields the Index by nothing more complicated than subtraction of the two pH values. For example: If the pH reading on the influent water is 8.0 and the effluent is 8.4 then the Index is $8 - 8.4 = -0.4$. All that this means is that the calcium carbonate hunger of the water had not been completely satisfied in treatment by the amount of carbonate to raise the pH value 0.4 more. Had the pH value not changed the Index would have been 0, indicating a perfect balance—a saturated water. Had the pH value been 8.8 at the influent and 8.4 at the effluent the Index would be $8.8 - 8.4 = +0.4$, indicating a sludge or scale depositing water—commonly referred to as unstable water in softening practice.

Question of Contact

An important question in connection with operating the Stability Indicator is how much of a contact period is to be required?

The answer is that this varies with various waters and the period must be determined. Ordinarily two hours will prove an ample contact with finely pulverized carbonate, and even one-half this period may prove ample in practical operating control. However, there is not any reason why the rate of feed should be more than a dribble, for there is no such thing as too long a contact period in respect to complete stabilization of water with calcium carbonate.

As a contact material for the Indicator precipitated chalk was suggested originally as the most effective material for the primary contact tube. Experience, since, has shown that if the tube is filled with the dry powder, when it is later wetted it swells sufficiently to choke the tube—and cause the stoppers to blow out, or else the tube breaks due to pressure. In consequence finely-ground marble or limestone has proved the more practical charging material. Precipitated chalk has, however, been successfully employed if the tube is only partially filled before wetting, or if the tube is filled with alternately placed 2-inch layers (charges) of chalk and chips of marble, limestone or material which prevents the chalk from packing and later swelling to choke the tube when wetted.

The Continuous Indicator has been constructed by many operators in many forms and shapes. So long as the contact is ample in respect to the calcium carbonate employed, and the trap is ample to preclude sweeping through of finely divided chalk, the dimensions and style of the contact chamber are of little consequence. In this matter the sufficiency of contact can be readily determined by making a test or alkalinity titration, then shutting off the water flow, and after several hours of quiet contact of the water with the carbonate employed replacing the Indicator in operation and making check tests for pH and alkalinity. If on the check tests the pH or alkalinity is up the operating rate is too rapid, the contact deficient. In the same manner by increasing the rate of flow through the apparatus one may determine the permissive maximum rate or minimum contact at which it is safe to operate the Indicator.

Some have employed Wolfe Bottles and others separatory funnels. The latter of flasks shaped like a spinning top. Water enters at the center with an upward flow and floats the precipitated chalk "sludge blanket" (picture the Spaulding Precipitator and you have the scheme) and leaves at the top to pass through the trap tube or a flask filled with marble chips or similar material.

Several Indicators of the non-breakable style have been fabricated from 2-inch copper tubing with satisfactory results. The only objection, if it be such, is the fact that one cannot see "the wheels go round" on the inside of these permanent tubes. They do look very "spiffy" though when all polished up.

CORROSION CONTROL AND STABILIZATION BY THRESHOLD TREATMENT

By OWEN RICE, Research Engineer
Hall Laboratories, Inc.
Pittsburgh, Pa.

The prevention of scale formation from hard or from unstabilized lime softened water has been one of the most stubborn problems for water plant operators to solve. This scale may be very troublesome for it causes incrustation and cementation in the filters and deposits in the pumping equipment, mains, valves, meters, heating coils, hot water pipes, and in cooling systems.

Prevention of scale formation may be accomplished by softening with zeolite, by acid treatment, or by lime softening followed by recarbonation. However, if any of these processes are carried too far, the treated water becomes corrosive. Controlled protective scale formation in connection with any of the above named processes, while theoretically offering much promise, has been found to be very difficult in practice.

For naturally soft corrosive water or zeolite softened water, it is not unusual to add lime or soda ash in order to raise the pH and to endeavor to produce a protective scale. This treatment has been found to be very seldom adequate, for the reason that too much of the precipitation takes place near the plant and not enough at the far ends of the distribution system to secure the protection sought. It also frequently causes trouble due to the formation of scale in hot water heaters and lines because a water saturated with calcium carbonate at room temperature becomes supersaturated when heated.

With waters softened with lime or lime and soda ash, recarbonation of the treated water before filtration is practiced for the purpose of neutralizing any excess lime and for converting the carbonates of calcium and magnesium into soluble bicarbonates, thus preventing after-precipitation. However, if carbon dioxide is added in sufficient quantities to change the normal carbonates to bicarbonates and so prevent after-precipitation, a new problem is introduced. Some of the finely divided calcium carbonate is redissolved during carbonation, thus increasing the carbonate hardness of the filtered water and, in addition, the pH is lowered to such an extent that difficulty is experienced with corrosion.

Threshold-Treatment with Calgon

Threshold-Treatment offers an entirely new approach to this problem. A development of Hall Laboratories, it consists in adding a very small quantity of sodium hexametaphosphate $(NaPO_3)_6$ to the water. The addition of only 1 or 2 ppm. of this chemical, which is marketed under the trade name "Calgon," to hard water or lime-soda softened water prevents all further precipitation of calcium carbonate. This fact is effectively illustrated in Figure 1.

In addition, the metaphosphate is adsorbed on metallic surfaces and the coating formed appears to be very effective in decreasing the attack of oxygen. Thus, "Threshold-Treatment," the terms selected to indicate the use of these very small amounts of Calgon, is of advantage in the stabilization of water for two reasons. (1) A higher pH may be maintained in the water in the presence of the Calgon without encountering difficulty due to excessive precipitation of calcium carbonate either in the distribution system or in hot water heaters. (2) The Calgon itself, by its adsorption on the surface of the metal, will form a protective film which decreases corrosion.

Plant Test at Delaware, Ohio

The Delaware, Ohio, municipal water plant, which is under the supervision of Mr. C. P. Hoover, was chosen for the first application of Threshold Treatment to a municipal lime-soda softening plant, as reported in W. W. & S. of January 1939. This plant pumps an average of 700,000 gallons per day and has been softening the supply since 1915. By the addition of lime and soda ash, the hardness of the water is reduced from an average of approximately 300 ppm. to 100 ppm. Recarbonation has been practiced since 1923, but in order to avoid dissolving too much colloidal carbonate, recarbonation is not carried to the point where after-precipitation of calcium carbonate is prevented. As can be seen by an examination of the data given in Table I, the average drop in alkalinity through the filters was approximately 30 ppm. From these figures it can be seen that the filters were playing a very important part in the softening process. During the first twenty-four days of May, the alkalinity of the settled water at Delaware averaged 64 ppm., while that of the filtered averaged 31 ppm. showing an average precipitation of calcium carbonate of 33 ppm. on the filters. A feed of 2 ppm. of sodium hexametaphosphate was started on the twenty-fifth day of May. There was practically no precipitation of calcium carbonate on the filters following this addition. The results are shown in Table No. I and Figure II. The results of Threshold Treatment during June, July, and August are also shown in Table I. During the latter month, the feed was reduced to 1 ppm. and then to ½ ppm.

Fig. I.—Effect of Threshold Treatment

Both bottles filled with water containing 250 ppm. of calcium-bicarbonate. To bottle "B" was added 2 ppm. of hexametaphosphate — (trade name "Calgon")—before adding 300 ppm. of soda ash to each. Results—calcium carbonate clouds appeared in "A" within 5 minutes; in the "Calgon" treated bottle "B" no precipitation is visible 24 hours later.

See Table I for long period results.

The effects of "Threshold Treatment" with 2 ppm. of "Calgon" as a precipitation preventive are strikingly evident.

It is evident that the after-precipitation of calcium carbonate was entirely prevented even at these lower feeds.

Results Were Striking

While this demonstrated strikingly the tremendous effectiveness of sodium hexametaphosphate in preventing the precipitation of calcium carbonate, it had the disadvantage of preventing the ad-

TABLE I.

Effect of Threshold Treatment on After-Precipitation at Water Softening Plant, Delaware, Ohio.

Average Results in P.P.M.*

	Alkalinity			Hardness	Pptd.
Period	Settled	Filtered	City Tap	Filtered	on Sand
1937	69	39	..	108	30
1938—January	76	51	..	118	25
1938—February	70	34	..	95	36
1938—March	68	35	..	94	33
1938—April	66	38	..	99	28
1938—May**	67	38	..	99	28
1938—June	67	66	60	106	1
1938—July	69	69	66	104	0
1938—August	72	73	71	103	—1

*Data obtained from the Ohio State Board of Health.

**Threshold treatment with 2 ppm. was commenced at noon, May. 25.

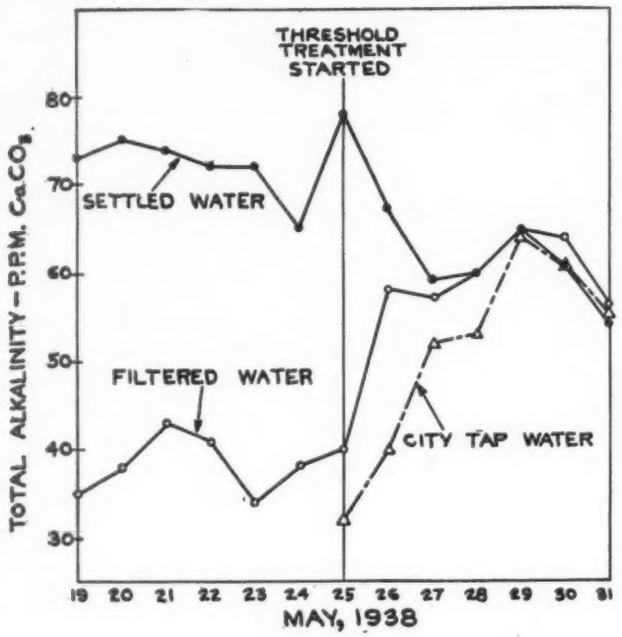


Fig. II.—The Effect of Threshold Treatment at the Delaware, Ohio, Softening Plant.

ditional softening secured on and within the filter beds. Consequently, where it is desired to obtain the softening action of the filters, the sodium hexametaphosphate should be added following filtration. It will then stabilize the filtered water and will prevent precipitation throughout the distribution system. A test made on samples drawn from hot water taps in cities where the water has been treated with Calgon showed that little or no precipitation was occurring even when the water was heated.

Threshold Treatment of Hard Waters

It has been difficult or even impossible from a practical standpoint to prevent the sealing up of hot water heaters when water high in hardness and bicarbonate alkalinity is used, except by softening the supply. In Figure III, however, the effect of 2 ppm. of sodium hexametaphosphate in preventing the precipitation of calcium carbonate when water high in bicarbonate hardness is heated is shown. These curves revealed very conclusively that threshold treatment would prevent excessive scaling of hot water heaters. Actual field tests made over periods of a year on waters of varying hardness have proved that the presence of 2 ppm. of Calgon was fully as effective as these laboratory tests had indicated, and scale formation was entirely prevented.

Threshold Treatment in Corrosion Control

The addition of lime or other alkali to the water in order to reduce the corrosion normally occuring has become fairly widespread. Difficulties experienced with this treatment were mentioned earlier in this paper. The ability of Calgon to prevent the precipitation of calcium carbonate regardless of pH permits the water plant operator to raise the pH to any value desired, since he is no longer limited by the calcium carbonate stability value; and, he can maintain this pH throughout the distribution system. During the past year, several municipal water plants have utilized Calgon along with lime and have obtained very good results in the control of corrosion. These plants have maintained a pH of from 9.4 to 10.4 throughout their distribution systems. While these results were to be expected from the action of Calgon in stabilizing the water, it is surprising to learn that other plants have obtained very good results by the addition of the Calgon alone as described below.

Several municipal water plants are using Calgon alone for corrosion protection and have reported good results even at pH values as low as 6.0. The results obtained to date seem to indicate that 1 or 2 ppm. of Calgon is more effective in decreasing corrosion than is the maintenance of a high pH value. It may well be, however, that best results in some instances will be obtained by the use of Calgon at a high pH value.

Theory and Testing of Threshold Treatment

The best explanation advanced for the ability of Calgon to stabilize water and prevent the precipitation of calcium carbonate, as shown in Figure I, is that the sodium hexametaphosphate is adsorbed on the nuclei of calcium carbonate preventing growth of the crystals and so stabilizing a condition of supersaturation. Considerable evidence is available that hexametaphosphate is similarly adsorbed on the surface of all metals and metallic oxides and that the metaphosphate film which is formed protects the surface from corrosion. In making tests on the effect of sodium hexametaphosphate on corrosion as well as on calcium carbonate stabilization, it is necessary to keep in mind that this effect is due to the adsorption of metaphosphate on the surface with which the water comes in contact. Consequently, it is necessary that a considerable quantity of water containing the metaphosphate be allowed to pass in contact with the surface before this adsorbed film reaches a thickness which gives it its maximum effectiveness.

Thus, in the familiar marble test where a very large surface of calcium carbonate is in contact with the water, it is necessary to use the same powdered calcium carbonate over and over again before the full effect of Threshold Treatment becomes apparent. This is because the metaphosphate is adsorbed from the water on to the surface of the calcium carbonate. This effect is demonstrated by Figure II giving the results at Delaware where three days were required in order to coat the surface of the filter sand

It is especially important to keep this fact in mind when making tests on corrosion protection. In the laboratory, the inhibting action of Threshold Treatment may be demonstrated by passing a continuous stream of water over the test specimen. In general, the higher the concentration of Calgon in the water being passed through the apparatus, the smaller the amount of water which must be used in order to reach a minimum rate of corrosion. Quantitative tests may be made by running the water through steel wool and measuring the oxygen content of the influent and effluent water. Such tests will show that oxidation of iron in contact with the threshold treated water occurs at a rate which is only a small fraction of that occurring in the untreated water. It is obvious from a consideration of this factor that corrosion tests cannot be made by inserting a test specimen in a beaker of water which contains a milligram or so of Calgon. It is necessary to more nearly duplicate plant conditions where there is always a fairly large ratio of water to iron surface and where freshly treated water is being continually brought in contact with this surface. Such can be readily demonstrated.

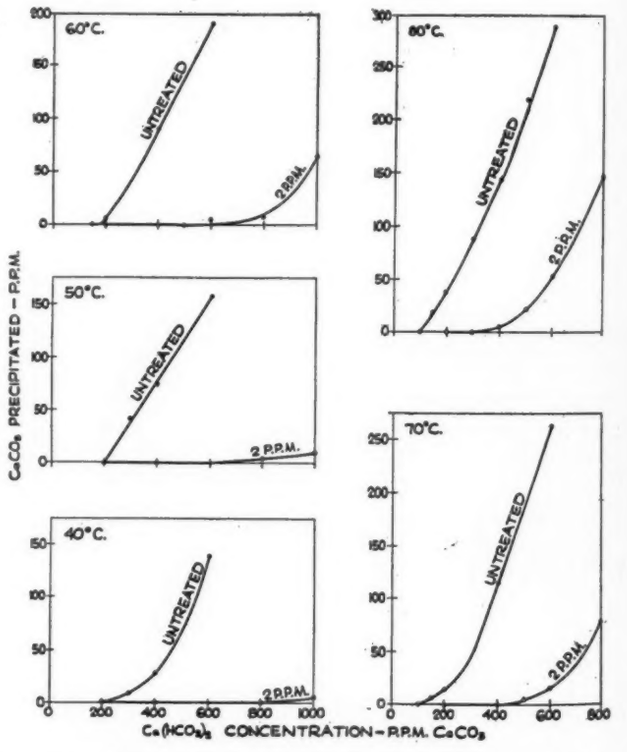


Fig. III—Samples of water of Various Degrees of Hardness Before and After Heating to Various Temperatures Indicated for One Hour.

LINK-BELT COMPANY

PHILADELPHIA
2045 W. Hunting Park Ave.
CHICAGO
300 W. Pershing Road
LOS ANGELES
361 S. Anderson St.
CLEVELAND
548 Rockefeller Bldg.
Atlanta..Baltimore..Boston..Buffalo..Dallas..Denver..Detroit..Grand Rapids..Houston..Huntington, W. Va...Indianapolis..Kansas City, Mo...Louisville..New Orleans..New York..Oakland, Calif...Pittsburgh..Portland, Ore...Salt Lake City..Seattle..St. Louis..St. Paul..Wilkes-Barre
In Canada—Link-Belt Limited—Toronto Plant; Montreal; Vancouver; Swastika

SETTLING TANKS

STRAIGHTLINE collectors for rectangular tanks and CIRCULINE collectors for round tanks assure

Positive and Rapid Sludge Removal

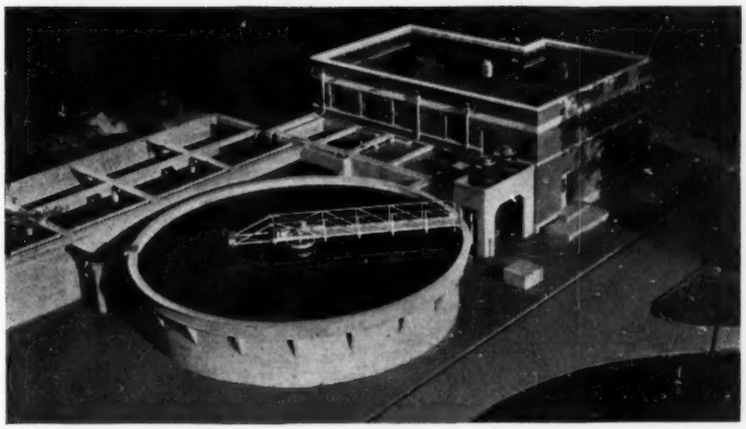
Sludge is conveyed to the sludge hopper over the shortest possible path and in the shortest possible time.

No Stirring Action

The action of the collectors is positive and the travel speed of the collectors can be adapted to the characteristics of the sludge so that very little stirring action takes place, the sludge being carried as a unit to the point of discharge.

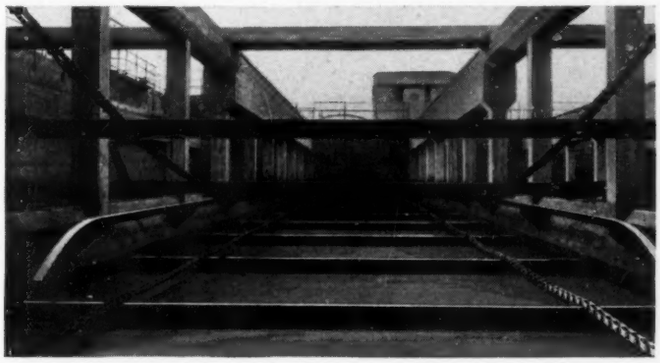
Efficiency

The slow speed of the collectors and the excellent distribution of flow assure the maximum efficiency in the removal of the suspended solids.

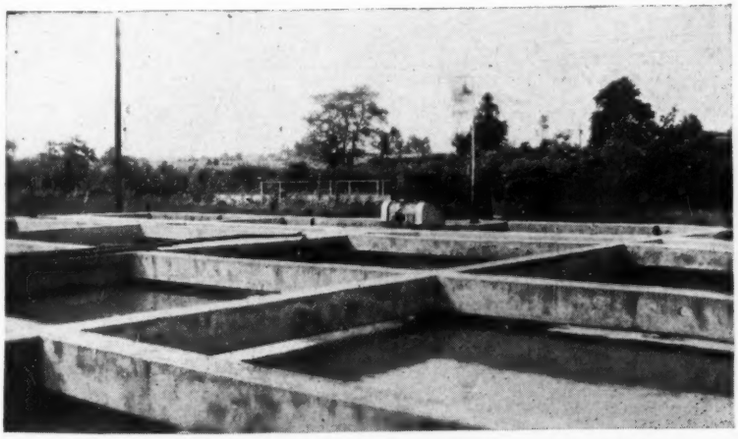


ST. AUGUSTINE, FLA., WATER SOFTENING PLANT

● *The Link-Belt CIRCULINE sludge collector in service at this plant has proved highly efficient in the positive removal of lime sludge from the settling tank at this water softening plant.*



● *Link-Belt STRAIGHTLINE sludge collectors are also being used with very satisfactory results at many other softening and filtration plants throughout the country.*



FREDERICKSBURG, VA., FILTRATION PLANT

● *Since the installation of Link-Belt horizontal mixers at this filtration plant, the city has reduced its alum cost 25% and its lime cost 50%.*
Other types of Link-Belt mixing equipment are available to meet particular conditions.

MIXING APPARATUS

Thorough mixing is essential to bring about a reduction in chemical costs and promote efficient flocculation of water.

Whether air or paddle mixers are the most advantageous depends upon the characteristics of the supply to be treated.

Link-Belt furnishes horizontal or vertical rotary paddles for mechanical mixing.

LINK-BELT WATER PURIFICATION AND SEWAGE TREATMENT PLANT EQUIPMENT INCLUDES: STRAIGHTLINE Collectors . . . CIRCULINE Collectors . . . STRAIGHTLINE Mechanically Cleaned Bar Screens . . . Tritor Screens . . . STRAIGHTLINE Grit Collectors and Washers . . . Tark Fine Screens . . . Equipment for Flocculation Tanks . . . STRAIGHTLINE Mechanical Aerators . . . STRAIGHTLINE Scum Breakers for Digestion Tanks . . . Elevated Aerators—Elrod Systems . . . Reciprocating Distributors . . . Traveling Water Intake Screens . . . Industrial Waste Screens . . . and a complete line of elevating and conveying equipment for all materials; power transmission equipment, and all accessories.

INTERNATIONAL FILTER CO.

Water Conditioning, Sewage Treatment, Hydraulic Control and Chemical Feed Equipment

325 W. 25TH PLACE, CHICAGO, ILL.

PRODUCTS

Aerators—MultiCone, forced draft, coke tray, cascade and spray
Boiler Water Purification Plants
Carbon Purifiers—Taste, odor and color removal plants
Chemical Feeders—Dry and solution types, combination mixers and feeders
Color Removal Plants
Controllers—Chemical feed, rate of flow, liquid level, hydraulic valve
Filters—Concrete and wood gravity, pressure, and disk type water filters; also milk, oil removal, swimming pool, etc.
Filter Plant Equipment—Controls, gauges, flow meters, indicators, recorders, operating tables, transfer switches, coagulators, etc.
Fluorine Removal Plants
Gauges—Rate of flow, liquid level, etc.
Iron Removal Plants
Lime Feeders and Slakers
Proportioners—Acid and chemical feed
Sewage Treatment Equipment—Activators, coagulators, clarifiers, dosing siphons, rotary distributors, samplers
Softening Plants—Lime-soda, Hot-flow, Accelator, Zeolite.
Steam and Gas Purifiers
Sterilizing Equipment
Swimming Pool Equipment—Filters, cleaners, fittings, etc.
Taste and Odor Removal Plants
Venturi Tubes and Meters
Water Filters and Filter Plant Equipment
Water Softening Plants of all types
Water Stills
Zeolites and Zeolite Water Softeners

INFILCO SERVICES

International Filter Co. designs and manufactures equipment for water conditioning, sewage treatment, chemical feed and hydraulic control to satisfy the requirements of municipalities, institutions and industrial plants.

A complete laboratory and staff of engineers are maintained to make unbiased reports and recommendations. This service is intended to cooperate and not conflict with the work of any representative or engineer of the purchaser.

ACCELATOR SOFTENERS, CLARIFIERS AND STABILIZERS

The Accelator for water softening, clarifying and pH correction is one of the most important water treatment developments in recent years. While retaining all of the advantages found in the conventional lime or lime-soda processes, it offers many new advantages. Treating, mixing, reaction and clarification, all are carried out in an incredibly small space. Treating chemicals are applied in a new way. Reactions occur under new conditions. Size is but a fraction of that for old type plants where design was based upon holding time requirements for chemical and physical reactions and for sedimentation.

CHEMICAL FEEDERS AND PROPORTIONERS

Infilco Chemical Feeders—dry or solution—provide means for volumetrically or gravimetrically measuring and feeding chemicals in any form: liquid, powdered, granulated or lump. Capacities are from a fraction of a pound to hundreds of pounds per hour.

Infilco Continuous Lime Feeders and Slakers combine in one continuous, automatic process, the consecutive operations of feeding and slaking crushed or pebble quicklime, followed by the preparation and delivery of a suitable milk of lime mixture.

Infilco Proportioners maintain predetermined ratios between liquid or solid flows, or automatically vary the ratio of one flow with respect to another, by electric, hydraulic or mechanical means.

COAGULATORS

Infilco Coagulators promote economy and efficiency in the chemical treatment of water and sewage. The applied chemicals are fully utilized by bringing them into intimate contact with the liquid undergoing treatment. The suspended particles are collected rapidly and quickly aggregate into masses having very high subsiding values.

CONTROLLERS, GAUGES AND METERS

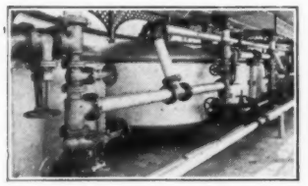
Infilco Rate of Flow Controllers, for automatically maintaining uniform rates of flow, are noted for their accuracy, low loss of head, reset and rate setter features. Infilco Water Level Controllers operate hydraulically controlled valves to maintain proper liquid levels.

Infilco Indicating and Recording, Rate of Flow, Loss of Head and Liquid Level Gauges and Illuminated Indicators provide visual indication and permanent records of plant operation.

Infilco Meters accurately measure the flow of a liquid through an Infilco Venturi Tube, and indicate, record and totalize such flow.

FILTER PLANT EQUIPMENT

There is Infilco equipment available to satisfy every filtration plant requirement. In addition to those items mentioned elsewhere on this page, there are Filter Operating and Control Tables, Filter Underdrain Systems, Mixing Basin Equipment, Pipe Gallery Specialties, Sampling and Observation Tables, etc. —Every type of equipment required in a filter plant.



RECARBONATORS

Infilco Recarbonators are available for the stabilization or recarbonation of industrial liquids, trade wastes and lime-softened water. Infilco equipment provides for the complete process of producing, cooling, scrubbing, compressing, drying and applying carbon dioxide gas to the liquid.

AERATORS

To permit selection of the proper type of aerator to meet conditions of head and space available, character and quantity of water to be handled, and results desired, Infilco offers its MultiCone, Forced Draft, Coke Tray, Cascade and Spray Type Aerators.

SEWAGE TREATING EQUIPMENT

Infilco equipment for the chemical, biological and mechanical treatment of sewage and industrial wastes includes: Activators, Chemical Feeders, Clarifiers, Digestors, Flow Measuring Equipment, Hydraulic Controls, Lime Slakers, Mixes and Coagulators, Proportioners, Rotary Distributors and Dosing Siphons, Samplers, Venturi Tubes anl Meters.

WATER SOFTENING*

With Particular Reference to Its Economic Aspects

By CHAS. P. HOOVER

Superintendent of Purification

Columbus, Ohio

The consumer judges water to be hard if much soap is required to produce a lather, and soft if it lathers freely. The hardness of most water supplies is due to four compounds which are held in solution. These compounds are:

1. Calcium bicarbonate (solution of limestone, $CaCO_3$, in waters containing carbon dioxide, CO_2).
2. Magnesium bicarbonate (solution of magnesite, $MgCO_3$, in waters containing carbon dioxide, CO_2).
3. Calcium sulphate (in the form, $CaSO_4.2H_2O$, is known as gypsum).
4. Magnesium sulphate (in the form, $MgSO_4.7H_2O$, is known as epsom salts).

As long as any of these compounds or a combination of them are present in a water supply it is hard.

Chlorides and nitrates of calcium and magnesium are sometimes present.

Calcium and magnesium bicarbonates were formerly designated as temporary hardness, but are now termed carbonate hardness.

Calcium and magnesium sulphates, chlorides, and nitrates were formerly designated as permanent hardness or incrustants, but are now usually called non-carbonate hardness.

Water softening processes remove objectionable iron compounds and manganese as well as hardness.

In general terms, hard water is made soft by a treatment which changes calcium and magnesium compounds from a soluble to an insoluble form, and then by removing the insoluble compounds by sedimentation and filtration, or by an exchange process, which consists in replacing the calcium and magnesium with sodium. The first process is known as the chemical, or lime-soda process, and the second, the zeolite process.

[Elsewhere in this issue appears a map of the United States which reveals the average hardness of public water supplies of important American municipalities, of each State.—*Ed.*]

History

The art of water softening with lime dates back to the year 1766 when Cavendish discovered that the addition of lime to natural water caused a deposition of the carbonates of calcium and magnesium. The proposal to use lime for softening hard water on a plant scale was advanced by Thomas Henry in England about 1800, but it was not until 1841 that water softening on a large scale was developed by Dr. Thomas Clark of Aberdeen, Scotland. He patented the process of adding lime to water to precipitate earthy carbonates held in solution by carbonic acid.

Winnipeg, Canada, built the first municipal plant in 1901. In 1903, the first municipal plant in the United States was built at Oberlin, Ohio.

In 1908, water softening on a larger scale than had hitherto been tried was undertaken at Columbus, Ohio, when a plant having a capacity of thirty million gallons per day (now 50 m.g.d.) was constructed.

For years the advantages of water softening were offset to a certain extent by disadvantages. Difficulties arose in operating sand filters on account of incrustation of the sand with calcium carbonate. Water mains, service pipes and meters became clogged with heavy deposits. When water contained an excess of causticity it was unpalatable. The recarbonation process developed by Archbutt and Deeley in the latter part of the last century, was employed at several plants in England for the purpose of overcoming all the above difficulties, but its first employment in this country, on a successful plant scale, was in 1921 at Defiance, Ohio. Since that time practically all water softening plants have been equipped with recarbonation devices.

The chemistry of water softening is now well understood, and an exact prediction of the results to be obtained can be made. Improvements in design and equipment for applying chemicals and removing sludge all tend toward simplifying operation. As a result of these improvements there has been a decided trend toward some degree of water softening by municipalities throughout the United States. Industry has gone forward with water softening to a far greater extent because of proven economies in processes, materials and equipment where soft water is made available.

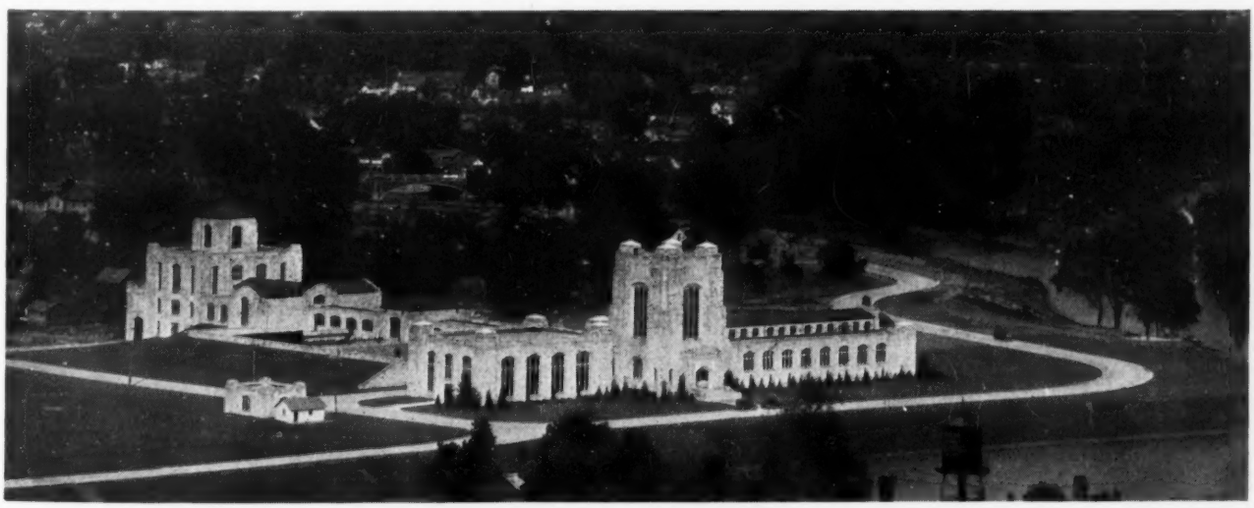
Economic Aspects of Water Softening

The water supply in a large number of cities and villages should be softened because:

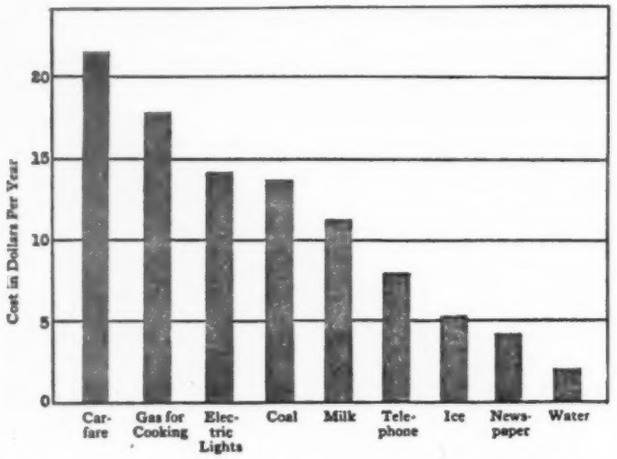
1. Hard water destroys soap; makes household work more difficult; has a bad effect on clothes washed in it, on plumbing, heating systems, boiler tubes and shells; and is unsuitable for many industries.
2. Softening at a central source of supply rather than in thousands of homes is economically sound.

It is cheaper to pay a reasonable additional charge for centralized softening than to accept a hard supply, a portion of which must be softened in the home. All of us, whether we

* Excerpts from "Water Supply and Treatment"—written by Mr. Hoover and published by the National Lime Association.



The Water Softening Plant of Fort Wayne, Indiana



Cost Per Capita Per Year for Domestic Services (Family of Five)

know it or not, soften some water each day, for it is necessary to use soft water to keep clean.

All public water supplies contain some hardness and that portion of the water in which soap is used must be softened to be effective. Soap has very little cleansing action until it lathers and it will not lather until the hardness salts in the water have been neutralized by it.

Aside from the objections of the precipitated soap curd, the extravagance of removing hardness with soap can be appreciated when it is realized that a pound of lime costing approximately one-half cent will neutralize as much hardness as 20 pounds of soap costing approximately $3.00.

Soap Losses Determined Experimentally

The amount of soap consumed and the quantity of water used for household processes, laundering, dish-washing, cleaning, washbowl activities, and bathing, was carefully measured for a period of one week, and calculated for a year.[1] Two kinds of water were used, each for one week: (1) Scioto River water which was filtered and sterilized but not softened. The hardness was 270 parts per million (16 grains per gallon). It was delivered in 10-gallon bottles to the home where the experiments were made. (2) Softened water as delivered to consumers. The hardness averaged about 80 parts per million (4.7 grains per gallon). In the home where the experiments were made there were five people, three adults and two children. Ivory soap in bar and flake form was used, the former costing 21 cents per pound and the latter 31 cents. The laundering was done in a vacuum type electric washer, the weight of the clothes averaging 29 pounds per washing.

Water-works records show that this family used the average quantity of water, about 30 gallons per day per capita. Their bill amounted to 75 cents per month. The soap was dried and weighed before and after it was used, so that the difference in weight would represent the weight actually used. The results for the week figured to one year show:

1. That this family used 281 gallons of water a week for ordinary household cleaning, divided as follows: Laundry, 15 gallons; dish-washing, 73 gallons; cleaning, 4 gallons; bathing, 136 gallons; and washing of hands, 53 gallons.
2. That approximately 11.46 pounds of soap were used per week with unsoftened water, or a total of 596 pounds per year.
3. That approximately 3.7 pounds of soap were used per week with Columbus city softened water, or a total of 192.5 pounds per year.
4. That softened water saved this family 403.5 pounds of soap per year.
5. That this soap, valued at 20 cents per pound, represented a saving of $80.70 per year and figured at 12 cents a pound, the price of cheaper laundry soaps, represented a saving of $48.42.
6. That this consumer could afford to pay five or six times as much for softened as for unsoftened water.

The investigation also disclosed the following facts:

1. One-half again as much time was needed to launder clothes in the unsoftened as with the softened water.
2. The cleanliness of clothes washed in the unsoftened water was not entirely satisfactory. Several very soiled pieces had to be rewashed and all of the clothes had to be re-rinsed.
3. The general appearance of the clothes was unsatisfactory.

These figures may be high for the average family but they are fairly representative for a family of five living in moderate circumstances. There are 55,033 domestic services or consumers in Columbus, Ohio. Applying the above figures, if each one saves $48.42, the total saving would amount to $2,664,697.86. If this figure is divided by two because of the possible use of cheaper compounds to "break" the water, the saving would be $1,332,348.93. This amount is about eight or ten times the cost of chemical softening.

Relations of Soap Wastage to Quantity and Type of Water

The above experiment demonstrated that 8 gallons of water per day per person were used for household processes. This quantity was probably not all completely softened by soap. Other workers have made the following estimates of water completely softened per capita per day:

	Gallons
Foulk[2]	0.9
Report of Special Committee for Madison, Wis.	1.7
City of St. Louis[3]	1.0
Average	1.2

The amount of soap required to reduce the hardness of 1,000 gallons of water, one part per million, has been determined as being 0.2 of a pound (Foulk's formula: Pounds of soap consumed per 1,000 gallons $= 2 + 0.2H$).

Based on these assumptions, the loss per family of five using water of varying degrees of hardness is shown in the following table:

SOAP WASTAGE AND COST WHEN USING WATER HAVING HARDNESS VARYING FROM 150 TO 500 PARTS PER MILLION

Raw water hardness p.p.m	Hardness removed by softening	Hardness reduced to	Loss lbs. of soap per family of five per yr.	Loss per family of five per year*
150	65	85	28.5	$3.40
200	115	85	50.0	6.00
250	165	85	72.5	8.70
300	215	85	94.0	11.30
350	265	85	116.0	13.90
400	315	85	138.0	16.55
450	365	85	160.0	19.20
500	415	85	182.0	21.85

*Soap at 12 cents per pound.

Actual Survey of Retail Soap Sales

The economic effects of quality of water, with special reference to soap consumption in the home, were demonstrated by H. W. Hudson[4] in a field survey of retail soap sales in four cities of the middle west: Superior, Wisconsin, and Bloomington, Champaign-Urbana, and Chicago Heights, Illinois. A canvass of all retail stores selling soap in these cities was made by a personal investigator who compiled a complete record of soap sales. The soap sales and per capita soap consumption with different types of water are shown in the following tables:

TOTAL SOAP SALES IN FOUR CITIES

City	Annual soap sales, pounds	Annual soap sales, dollars
Superior, Wisconsin	1,530,314	$196,133
Bloomington, Illinois	1,517,658	215,528
Champaign-Urbana, Illinois	2,093,881	307,732
Chicago Heights, Illinois	1,009,503	159,910

PER CAPITA SOAP CONSUMPTION WITH DIFFERENT TYPES OF WATER

City	Total hardness of water supply p.p.m.	Annual per capita soap consumption pounds	Annual cost of soap per capita dollars
Superior, Wisconsin	45	29.23	$3.75
Bloomington, Illinois	70	32.13	4.48
Champaign-Urbana, Illinois	298	39.89	5.93
Chicago Heights, Illinois	555	45.78	7.50

[1]Thesis presented for the degree of Master of Science by Miss Pauline Snyder, Ohio State University, 1927.

[2]Geological Survey of Ohio, Bulletin 29, 1925.

[3]Report of Water Commission, 1922.

[4]Abstract of thesis for Doctor of Philosophy in Economics, University of Illinois, 1933.

The results show:

1. That soap bills increase as the hardness of the water with which soap is used increases.
2. That even with a relatively soft water, a considerable quantity of soap is required to remove dirt and grease.
3. That by taking Superior as a basis for comparison, the annual per capita soap waste is: Bloomington, 2.9 lbs.; Champaign-Urbana, 10.7 lbs.; Chicago Heights, 16.6 lbs.
4. That this loss in Chicago Heights would amount to $15.00 per year per family of four.

From the results of this study an equation was formulated to show the degree of hardness necessary in any particular water supply in order that the economy in soap obtainable by the use of soft water would pay for the cost of softening.

$$X = \frac{C - 75D + 75F}{F - D}$$

X = hardness of water supply in p.p.m., the softening of which will be paid for in soap economy alone.
75 = demonstrated attainable hardness of water in p.p.m., from municipal water softening plants.
F = soap waste per capita per year per p.p.m. hardness.
C = capital overhead charges, including superintendence, per capita per year.
D = cost of chemicals per capita per year per p.p.m. hardness.

Mr. Hudson states that if this equation is applied to data for Champaign-Urbana and the hardness of the raw water tested only 145 p.p.m. (it is actually 298 p.p.m.) a municipal water softener that would soften the water to 75 p.p.m. would save enough in soap for home use alone to pay for itself.

Effect of Hard Water on Power and Heating Systems

Heating hard water causes it to deposit scale in water pipes, heating coils, boiler tubes, and boiler shells. The heat loss due to scale, 1/50 to 1/9 inch thick, has been computed to be from 7 to 16 per cent.[5] This means that with scale 1/9 inch thick, 16 cents of every dollar paid for coal is lost. This is in addition to the trouble, cost of drainage, and time lost in getting rid of the scale. According to an estimate of the American Railway Engineering Association,[6] the damage caused by one pound of scale is 13 cents. The Association further estimates that the improvement in operating and maintaining locomotives, due to water softening, amounts to a saving of from $4,000 to $9,000 per locomotive per year.

Hard Water Stunts Growth of Cities

A study of ten Illinois cities shows[7] that eight have comparatively soft water supplies as judged by midwestern standards, whereas the other two have supplies that are excessively hard. The two hard water cities will be designated as A and B. Both are situated in rich agricutural sections and are advantageously located with respect to large markets. In spite of these advantages they have shown a very slow rate of growth. In 1880, A and B together had 26 per cent of the total population of the ten cities. In 1920 they together had only 13.7 per cent.

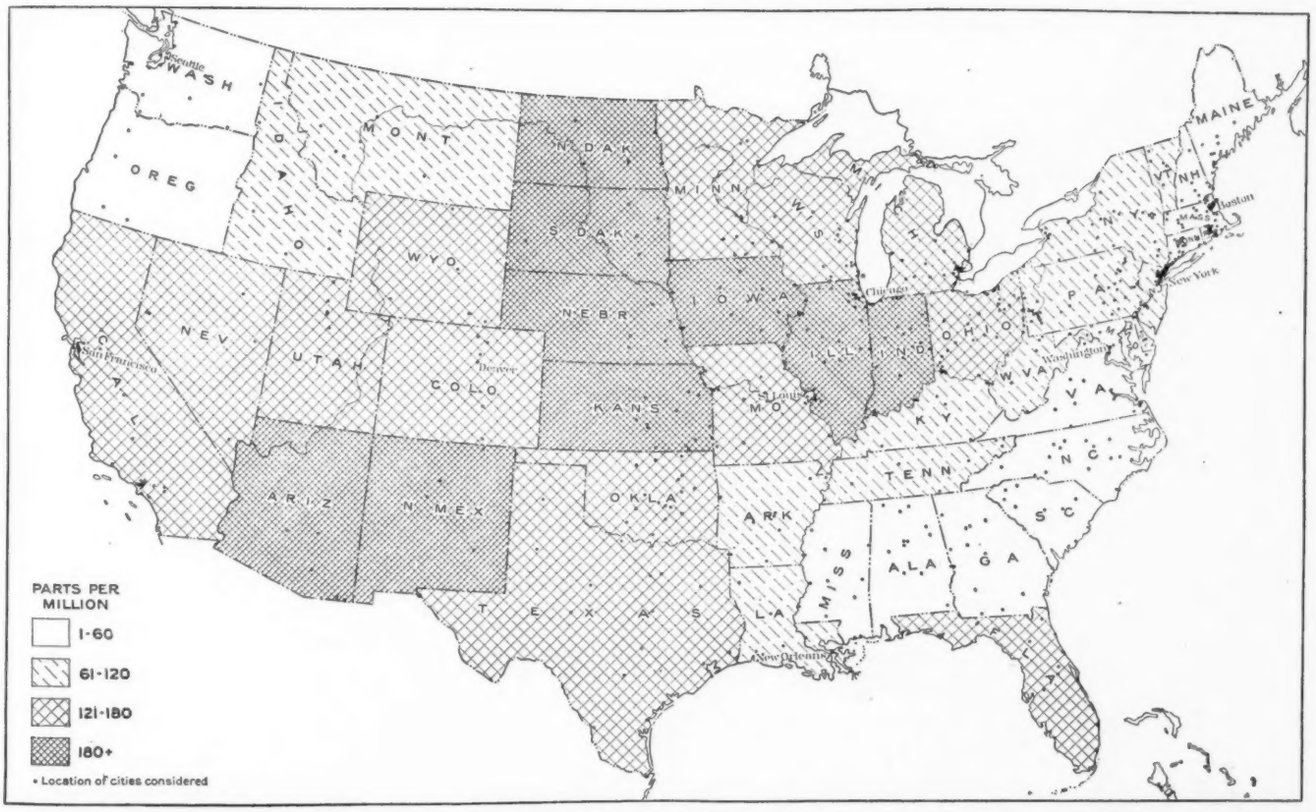
Manufacturing industries which require soft water for their successful operation, in establishing plants select communities having satisfactory water, other things being equal.

Cost of Softened Water vs. Other Commodities

"Cheap as dirt" is a common expression, but even expensively treated water is *much* cheaper! Two hundred and forty-one gallons of water equal one ton. Five cents a ton would be a little over 20 cents per 1,000 gallons, which is more than the average consumer pays for water in the larger and medium sized cities. A ton of dirt delivered would cost many times this amount.

The cost per capita per year for various domestic services by a family of five in Columbus, Ohio, is shown in the chart on the preceding page.

[5] U. S. Bureau of Mines, Tech. Paper 218.
[6] Bulletin, American Railway Engineering Association, November, 1923.
[7] Alvord, Burdick & Howson (Chicago), a private communication.



Weighted Average Hardness, by States, of Water Furnished in 1932 by Public Supply Systems in Over 600 Cities in the United States (Reprinted from U. S. Geol. Survey Water Supply Paper—658)

OMEGA MACHINE CO.

4010 Penn Ave., Kansas City, Mo.

REPRESENTATIVES

Atlanta, Ga.—W. D. Taulman, 175 Spring St., S. W.
Cleveland, O.—Paul Kittinger, 402 Western Reserve Bldg.
Detroit, Mich.—Wm. A. DaLee, Inc., 4835 Woodward
Hawaii—Alan Duvall, Box 33, Honolulu
Los Angeles—Chas. P. Crowley, 609 S. Anderson
Louisville, Ky.—R. M. Overstreet, 1441 S. 4th St.
New York City—Hanson Engineering Co., 50 Church St.
Toronto, Ontario—Control & Metering, 154 King St. West
Brazil—Oscar Taves & Co., Box 840, Rio de Janeiro
Colombia—MacDonald & Petersson, Ltd., Apartado 257, Bogota

EQUIPMENT

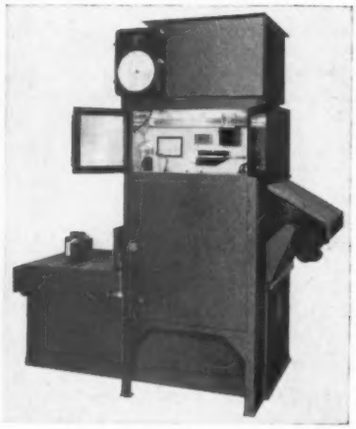
For Dry Material

Batch type Gravimetric Feeders
Belt type Gravimetric Feeders
Weighcheck Feeders
Universal Volumetric Feeders
Lo-Head Feeders
Disk Feeders
Dust Removers and Filters
Combined Bucket Elevators & Feeders

For Liquids

Precision Feeders
Rotodip Feeders
Proportioning Pumps
Laboratory Stirrers
Lime Slakers
High Speed Agitators
Slow Speed Agitators
Automatic Proportional Control

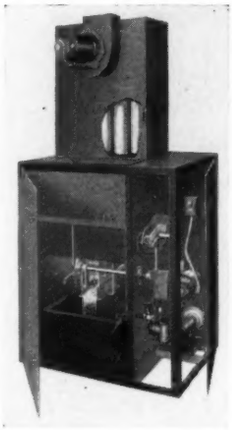
GRAVIMETRIC FEEDER AND SLAKER



A size No. 1 Gravimetric Feeder with 2,000 lb. hopper and mechanical operation recorder is illustrated mounted over a Lime Slaker. Slaker sizes range from 175 lbs. to 6,000 lbs. per hour.

In this type Gravimetric Feeder the entire hopper load of chemical is carried on the scales which control the rate of feed. Errors cannot be cumulative.

LO-HEAD FEEDER



Large hopper capacity with only 45" filling height. Rates of feed from 1 to 200 lbs. per hour. Cabinet type illustrated with feeding and driving mechanisms completely enclosed in separate compartments.

Any Omega feeder may be equipped with the dust remover and filter illustrated. The filter may be connected to several machines to remove dust incident to filling the hoppers with carbon, lime, etc.

BELT TYPE GRAVIMETRIC FEEDER

Weighs the material as it is fed on a short section of conveyor belt which is mounted on accurate scales. These feeders may be connected directly to large overhead storage bins if desired.

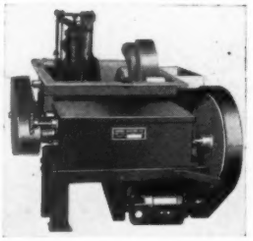
Accurate feeding range is from 5 lbs. to 3,000 lbs. per hour. A totalizer shows the number of pounds of material that have passed through the feeder.

PRECISION FEEDER

The most accurate and simplest type of feeder for solutions or light suspensions. Rate of feed is set by a dial to desired percentage of maximum rate. Feeding capacities range from 1/25 to 400 gallons per hour. Electric or spring motor drive.

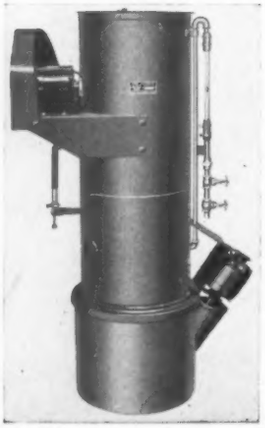
Tanks may be equipped with dissolving baskets and agitators for dissolving lump material. Tank sizes 25 to 400 gallons.

ROTODIP METER



For feeding from large supply tanks which may be located at a distance from the feeder. Feeding range 1 to 800 gallons per hour. Galvanized, rubber covered or plain steel construction. Variable speed drive gives an infinite number of speed changes from zero to maximum rate.

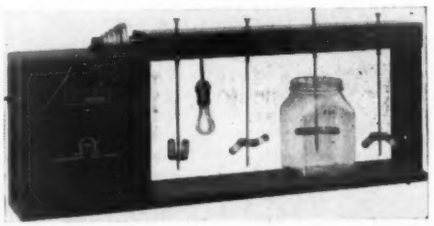
UNIVERSAL FEEDER



Rugged, accurate Volumetric Feeders. Designed to be used with extension hoppers or with overhead storage bins.

The No. 3 size Universal Feeder illustrated has a lead lined mixing chamber and motor driven, stainless steel agitator for dissolving Ferrisul. The water supply to the mixing chamber is measured by a Rotameter. Separate valves are used to regulate and to shut off the water supply.

LABORATORY STIRRER



For jar tests, to determine proper coagulant or carbon dosages. Also ball mill or tumbler type for agitating material in closed vessels, for threshold treatment tests.

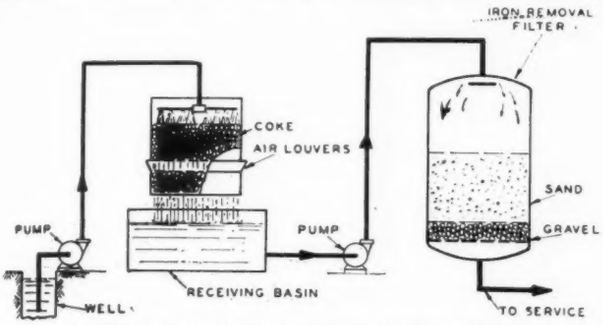
REMOVAL OF IRON AND HARDNESS

By DANIEL J. SAUNDERS

The Permutit Company, New York, N. Y.

The following describes some of the difficulties experienced in industry and in the home due to the presence of iron and hardness in water and, at the same time, outlines methods that can be employed to overcome such difficulties, under varying sets of conditions.

When iron is present in a water supply in an amount greater than 0.3 p.p.m., it causes unsilghtly yellowish or black stains on bathroom fixtures, gives a metallic taste to drinking water, reacts with other reagents used in dye houses, laundries, paper mills and tanners where, for example, it combines with tannin in leather and forms black iron tannate; deposits in Municipal distribution systems, thus not only increasing the friction through



A Simple Coke Aerator and Iron Removal Filter.

the mains which increases pumping costs, but at sudden high rates of flow these deposits loosen iron rust itself which is delivered to the users. Further, the growth of iron bacteria, such as Crenothrix, is also promoted by its presence.

The type of treatment plant required to remove iron is determined by a number of factors such as: character of the water (especially the factors interfering with oxidation reactions) engineering conditions and the purpose for which the water is to be used.

Iron and Manganese Removal

In general, iron (also manganese), can be removed from well waters by two methods:

1—Oxidation to the insoluble higher oxides and hydrates followed by filtration.

2—Removal by base exchange, by employing correctly selected base exchange zeolites.

However, all waters and particularly surface supplies, do not respond readily to oxidation reactions. As just mentioned, there are interfering factors to be given consideration such as:

Free Carbon Dioxide

High amounts of free CO_2 or any acid will interfere with the oxidation reactions going to completion. Therefore, in such cases thorough aeration, or addition of alkalis, or both, are necessary. The addition of only 0.14 p.p.m. of oxygen per 1 p.p.m. of iron is theoretically required in the normal oxidation reaction. This quantity is insufficient when free CO_2 or any acid is present.

Low Total Solids

With waters of this type usually, even though a thorough removal of the carbon dioxide is effected by efficient aeration, it is necessary to supplement that step in the treatment by additional steps, as will be described later.

Organic Matter

Iron or manganese present in organic combinations is not removed by simple aeration and filtration. Coagulants fed into floc forming aggitating devices to accelerate floc formation and sedimentation tanks or basins must precede the filters.

Excessive Aeration

This has been known to interfere with the complete removal of iron and especially manganese. In such cases, restricting the aeration, i.e., limiting the absorption of the oxygen to a fraction of saturation, gives better results.

Types of Plants

Waters Low in CO_2 and Relatively Low in Iron Responding Readily to Oxidation

A small amount of air can be introduced by sniffling air into the suction side of the well pump for oxidation purposes. The well pump can then pump the oxidized water directly through either a single pressure filter or, to avoid frequent backwashings, through a coarse pressure filter followed by fine pressure filter direct to storage or use, thus making repumping unnecessary.

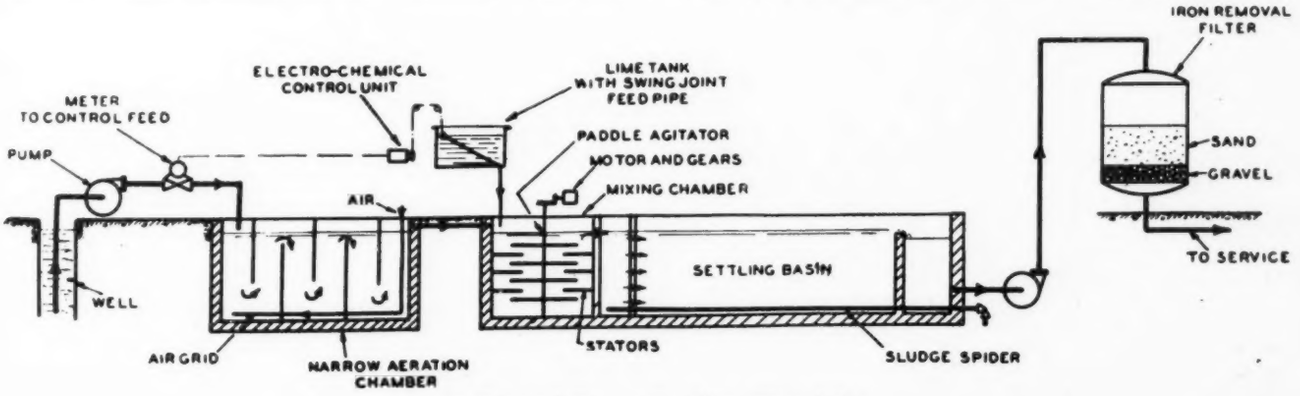
However, where preferred, gravity filters can be employed. Air wash systems should be employed where their use is deemed advisable.

Waters High in CO_2 Requiring CO_2 Removal by Alkali Feed or Efficient Aeration Before Final Filtration

In this case, the arrangement just described can be employed provided an alkali feed is installed to neutralize the CO_2. However, as air is free, if the quantity of water being pumped is appreciable, an efficient type of aerator should be installed, preferably either a coke tray type or degasifier bubbling type to insure exposing the water to the air in thin films or drops so that each particle of water contacts air low in CO_2 content. However, should the iron present in the raw water be very high, a sedimentation tank or basin may be required.

Waters of Low pH Value That Do Not Respond Readily to Oxidation

In such cases, following aeration, lime or soda ash is fed by means of a proportionating chemical feed to a sedimentation tank or basin (equipped with floc formers for aggitating purposes).

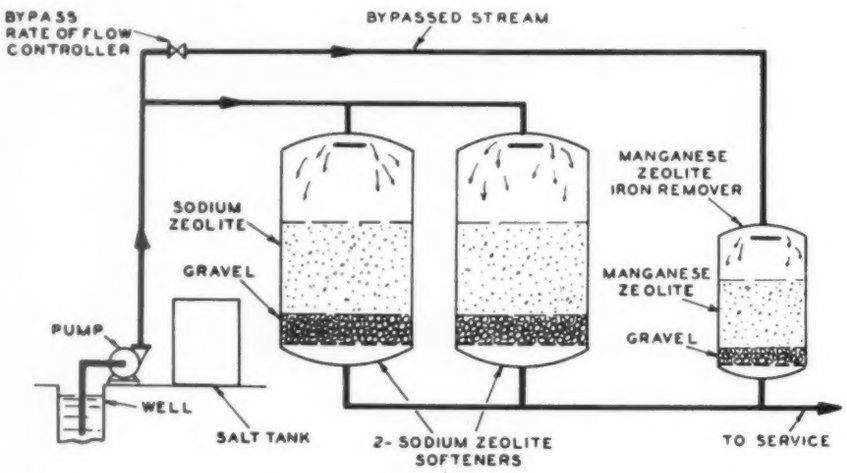


Iron Removal System Providing Flocculation.
Involving aeration, lime treatment, flocculation and clarification before filtration.

Lime is employed for the larger plants—soda ash for the smaller plants. Lime gives better results because it also has a coagulating effect. However, it also increases the hardness and as this is objectionable in many cases, soda ash is employed. The settled water is then pumped through filter equipment to either the mains direct or to storage and the mains.

Waters Containing Iron in Organic Combinations

The treatment suited to any given case of this kind will depend upon the type of organic compound present. The best treatment must be determined by experiments in the field and the laboratory. Further, the treating plant should be designed so that the pH values may be altered at will and also so that different coagulants may be added as required.



Combination Zeolite Softener and Manganese and Iron Removal Zeolite Units. Capable of producing iron free effluent of 4 to 5 grain hardness—favored in municipal installations.

Obviously, this will mean equipment for feeding various chemicals, sedimentation (and possibly double sedimentation) and filtration, plus chlorination.

Waters of Low Iron Content Where Reduction in Iron Content Should Be Below 0.1 ppm.

Manganese zeolite filters are most effective in the removal of iron where practically complete removal is desired for industrial purposes. Manganese zeolite consists of sodium zeolite treated by manganous chloride and oxidized by sodium or potassium permanganate. The manganese zeolite proper acts as an active carrier and catalytic reagent. The oxides themselves do the work of iron removal. These oxides give up oxygen to the water for the necessary oxidation reactions. They are re-oxidized by passing permanganate solution through the bed. Approximately 0.01 lb. of permanganate per thousand gallons is required for the average water. These filters are backwashed daily, but usually regenerated only at weekly intervals.

Sodium zeolite of the natural type, provided it has been correctly processed, or "Zeo-Karb" material, a carbonaceous zeolite, may be economically employed to remove iron and manganese by base exchange, at the same time that the zeolite is softening the water. When these types of zeolites are employed for iron and hardness removal by base exchange, the iron must be maintained in the *ferrous* form. Therefore,, well waters cannot be exposed to air before such zeolite treatment. The regeneration of units of this type is accomplished by the usual sodium chloride regeneration employed in zeolite softening.

Water Softening

There are five methods of water softening in general use. These are:

1. Zeolite Process—Sodium Cycle.
2. Zeolite Process—Hydrogen Cycle.
3. Cold Lime Soda Process.
4. Combination Lime Zeolite Process.
5. Hot Process.

Processes Nos. 1, 2 and 4 will reduce the hardness of the water to practically zero. Process No. 3, depending on the way it is carried out and also the composition of the raw water, will reduce the hardness from 3 to 5 grains per U. S. gallon. Process No. 5 will reduce the hardness to some figure below 1½ grains per U. S. gallon, depending upon the character of the water, the chemicals employed, etc.

Zeolite Process (Sodium Cycle)

With this method the hardness is removed by base exchange; the calcium and magnesium being retained by the zeolite while the corresponding sodium salts are found in the effluent. After the rated capacity of the zeolite to soften water to zero hardness has been exhausted, the softening capacity is restored by treating the zeolite with a solution of common salt.

As this salt solution comes in contact with the zeolite, the calcium and magnesium is removed in the form of the soluble chlorides, and its original sodium content is restored. After flushing the chlorides of calcium and magnesium, plus excess salt, to the drain, the zeolite is ready to soften a further equal quantity of the hard water.

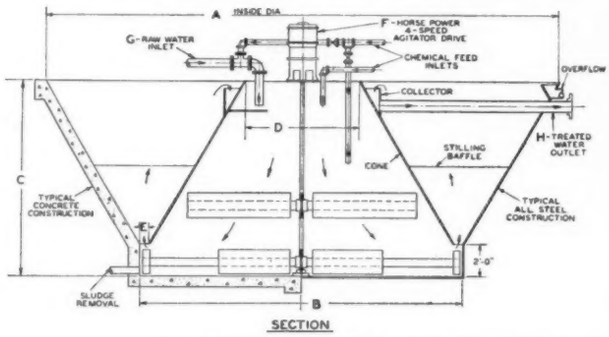
These alternate softening runs and regenerations can be repeated indefinitely, as the wear and tear on a correctly processed zeolite is negligible. Therefore, the annual cost of replacing this zeolite is correspondingly low. The effluent from a zeolite water softening plant is practically of zero hardness. As zero hardness water is either a requirement or at least desirable for most industrial processes, all of the water used in an industrial plant is usually passed through the zeolite plant. In the case of municipal zeolite plants, a zero hardness water is not required. Therefore, in such cases, enough hard water is bypassed and mixed with the zeolite softened water to yield a mixed effluent of the desired degree of hardness.

Zeolite water softeners are available to operate automatically through all cycles of operation by a combination of a motor driven multiport valve with electrical controls. Automatically, the equipment is cut out of service, backwashed, brined, rinsed and returned to service. About 90% of the more recent municipal zeolite water softening plants are of the automatic type.

Zeolite Process (Hydrogen Cycle)

In this process of water softening, a carbonaceous type of zeolite is employed. It is of especial value in softening waters of a high bicarbonate content, as the bicarbonates, of sodium, calcium, or magnesium, are replaced by carbon dioxide and water; the base being retained by the zeolite.

The carbon dioxide may then be removed by passing the softened water through a degasifier (bubbling) type of aerator. This process, therefore, in a very simple manner practically completely removes bicarbonates of all kinds.



Section Through the Spaulding Precipitator. The treated water is mixed with sludge (center) and rises upwards through the sludge blanket to the surface overflow.

At the end of the softening run, the carbonaceous zeolite is regenerated by treating it with a dilute solution of sulfuric acid. This restores the hydrogen content of the zeolite and simultaneously removes the bases in the form of soluble sulfates. These,

plus the excess of acid, are then flushed out to the drain, after which the zeolite is ready for the next softening cycle.

Cold Lime Soda Process

In this process, as carried out in the conventional type of equipment, the raw water is treated with regulated dosages of lime and soda ash. The bulk of the hardness precipitated by these chemicals, is then settled out in a settling tank having a detention period of at least 4 hours.

It is then either recarbonated and filtered or filtered and recarbonated. As usually carried out, the effluent so produced has a hardness of 5 grains per gallon.

In the relatively newer Spaulding Precipitator type of equipment, the treated water is brought into intimate contact with suspended sludge. This suspended sludge acts to produce a more stable effluent in a much shorter period of time.

In practice, it has been found that the Spaulding Precipitator requires only a one hour detention period and that the reduction of hardness is so complete that recarbonation is either carried out to a very slight extent or eliminated.

Combination Lime Zeolite Process

In the combination lime zeolite process of water softening, the bicarbonate hardness is reduced by treatment with lime. The lime treated water is then recarbonated, filtered and then passed through zeolite water softeners.

The net effect is that the lime treatment removes the bulk of the bicarbonate hardness and the subsequent zeolite treatment removes the non-carbonate hardness plus any residual bicarbonate hardness. In many cases, it has been found economical to employ this combination type of treatment because of the savings effected in the lower cost for salt vs. soda ash required per 1,000 grains of hardness removed.

For industrial processes or boiler water, all of the lime treated water is passed through the zeolite water softeners. Incidentally, when *any* water is used for boiler feed, it is important to give consideration to supplementary treatment so that the final reedwater will conform to modern power plant practice, as prescribed by the ASME. For municipal water supplies, only the requisite portion of lime treated water, required to produce a 4 to 5 grain per gallon hardness in the mixed effluent, is shunted through the zeolite water softening equipment and again joins the lime softened portion.

Hot Lime Soda Process

The hot lime soda process of water softening is carried out by adding carefully regulated dosages of lime, soda ash and/or other chemicals to the raw water, after heating it to a temperature at or near the boiling point. Since the high temperatures employed speed up the chemical reactions, a detention or settling period of only one hour is required. (This statement indicates the value of the Spaulding Precipitator which requires no heat input.)

The settled water is then filtered through filter beds of non-siliceous material. Depending on the excesses of chemicals used, the hardness of the effluent varies from as low as 1½ grain per gallon down to a fraction of a grain. As this process must be carried out hot, its application is obviously practically limited to the production of boiler feed waters.

* The content of this article is in part derived from a paper read by the author before the Michigan Section of A.W.W.A. and Michigan Conference on Water Purfication meeting jointly.

Sherwood Waterproofing Corp.

53 PARK PLACE **NEW YORK CITY**

WATERPROOFING MATERIALS

WATERPLUG

A quicksetting, permanent, waterproof material, applied to streams of running water or seepage through masonry walls stops leaks immediately.

WATERPLUG set in from three to five minutes, according to temperature of water with which it is mixed or to which it is applied. WATERPLUG is ideal for stopping water running or seeping through basement walls, elevator pits, cisterns, tanks or all rooms below grade subjected to water pressure. It is invaluable in anchoring bolts, machinery or equipment where speed and permanence is necessary. It has hundreds of uses aside from stopping water instantly, giving service in heat equally as well as in water.

When kept in a medium warm dry place, WATERPLUG will hold its strength and efficiency for several years and need never be lost through age.

WATERPLUG is a remarkable material, in that in its simplicity of application and effectiveness when applied against mild or extreme water pressure that any water condition arising in masonry structures can be controlled.

WATERPLUG is a dry, powdered material, which requires the addition of water only to make it ready for use.

WATERPLUG is as permanent as the structure to which it is applied. It is a non-shrink material hardening as effectively in extreme cold as in extreme heat.

QUICKSEAL

A dry, powdered material to be mixed with water only, and to be used as a brush coating on all types of masonry structures above or below grade. It flows readily into voids and over the surface of dampened masonry thoroughly sealing any porous conditions which may exist and permanently waterproofs the surfaces on which it is applied.

QUICKSEAL is ideal for waterproofing walls and floors of swimming pools, reservoirs, sewage disposal basins, tanks, pits, vats, cisterns, troughs, elevator pits, etc., where wearing surface is not essential; interior walls of basements of old buildings or exterior walls of new buildings, fire walls on the roof side, coping and cornices or any projecting surface that is subject to storm, moisture and frost.

QUICKSEAL restores and beautifies brick, tile and concrete walls of buildings above grade, where the masonry has become old and porous, checked and cracked. An old building can be made to look like new and dampproofed with QUICKSEAL.

QUICKSEAL, when applied to the exposed surfaces of grain elevators, reinforced concrete bridges, underground passages and tunnels and reinforced concrete monolithic sewers, preserves and protects against moisture entering the body of concrete, and the subsequent effects of frost.

THOROSEAL

A dry, powdered material to which only clear water is added to make it ready for use. It is applied with a trowel and finishes to a hard, smooth surface.

THOROSEAL is a slow setting material with waterproof film forming for several weeks after application. The waterproofing element in THOROSEAL after several weeks becomes harder than the cementitious base material and reaches maximum efficiency when subjected to weather and exposure to water and dampness. There is no oxidizing element in THOROSEAL and the flux used is a permanent filler which completely seals the material against penetration of water.

THOROSEAL is ideal for lining reinforced concrete tanks for storage of water, even though the concrete may be cracked and leaking or decayed.

DRY-JOINT

A waterproofing pointing mortar which when tucked into the joints of stone, brick, tile and terra cotta permanently seals against the entrance of moisture or water.

Many troublesome problems, wherein beautiful interiors are ruined by moisture entering through defective mortar joints, are corrected by pointing with DRY-JOINT.

DRY-JOINT is a dry material ready for use by simply adding clean water. It is a cementitious product and should not be confused with plastic materials.

TECHNICAL PAINTS

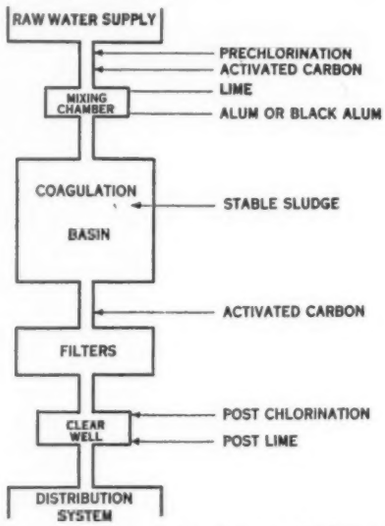
The constant demand for special paints to meet specific needs has resulted in the production of a long tested line of technical paints for every requirement:

ALUMINUM PAINT for inside and outside use.
DAMPPROOF CEMENT PAINTS and FLOOR ENAMELS.
STRUCTURAL PAINT for tanks, bridges and all metal surfaces.
WATERPROOFING and DAMPPROOFING LIQUIDS.
SMOKESTACK BLACK to resist heat.
ASPHALT EMULSIONS with and without asbestos fibre.
CAULKING COMPOUNDS.

ACTIVATED CARBON IN TASTE AND ODOR CONTROL

By E. A. SIGWORTH
*Industrial Chemical Sales Div.**
New York City

Progressive men in the water works field realize that by serving the public a water that is palatably attractive, as well as safe they are doing a real and appreciated service to the community. Toward this end activated carbon has filled a very real need, and now the use of the adsorptive purifying material has grown the world over. In speaking of "tastes and odors" in water it is well to keep in mind that we are principally concerned with odors rather than tastes.



Flow Sheet for Chlorine and Activated Carbon Applications

The Material

Activated carbon, as it is usually employed in water purification, is a fine black powder and accomplishes the removal of tastes and odors by a phenomenon commonly described as adsorption. In simple terms this means a concentration of the taste and odor producing substances on the surfaces of the carbon particles. Thus, when the carbon particles are removed from the water, the taste and odor producing substances are also removed. Since activated carbons are harmless, an overdose in a water supply will cause no greater difficulties than perhaps to add some slight amount to the cost of treatment. Activated carbons are also offered in granular form for contact units—in situations where the more economical powdered material is unpracticable.

Considering the great variety of odors which may be found in a water supply, the almost universal success in removal with activated carbon is truly remarkable. John R. Baylis[1] has stated "All tastes and odors likely to be present in a water supply can be removed with activated carbon.—We find a few statements in the literature on water treatment that the taste or odor was not removed by the addition of carbon, but almost invariably the reason was that not enough carbon was used." Along with its other many accomplishments, activated carbon is a very effective dechlorinator. Its use for this purpose has the very definite advantage that an overdose will have no ill-effects in the distribution system.

Methods of Application

Although activated carbon is not harmful to health when taken internally, its presence in a distribution system could be objectionable to the layman because of its black appearance. Thus, it is desirable to plan in advance for its removal in treatment processes. Application of activated carbon is therefore usually made prior to sand filtration. However, activated carbon has been successfully applied where no filters are available; the removal being accomplished by coagulation and sedimentation. Even where coagulation is not practiced, activated carbon has been successfully applied and removed by simple sedimentation. There are a number of instances where activated carbon has been applied in reservoirs without any coagulating aids and the carbon has been allowed to settle out of the water. Even if this method of application is not practical, there is still the granular form which can be utilized in a filter system or packed between screens through which the water is passed. Granular activated carbon has also been employed in bags, which are suspended at suitable points in the water system, whereby the water has an opportunity to come in fairly intimate contact with the carbon particles. However, activated carbon is most frequently applied in water systems where sand filters are available.

The powdered carbon can be applied by means of either solution feed or dry feed equipment. A survey made a few years ago showed that the most general feeding method employed was with dry feed equipment. Today practically every manufacturer of dry feed equipment has placed machines on the market that are specifically designed to feed activated carbon from minute quantities up to unusually large dosages.

Points of Application

No definite rules can be laid down for the proper point of application in order to secure optimum results. Conditions within the various water plants vary to so great an extent, from the viewpoint of equipment, design, types of water, types of pollution, and intensity of tastes and odors, that the best means of determining the proper point of application seems to be by a trial and error method.

The above mentioned survey revealed that the point of application most commonly utilized is prior to, or during coagulation. When activated carbon is applied at this point, it has a longer time in contact with taste and odor producing substances, and also carriers through the basins giving a stabilizing effect on the sludge which settles out. Where tastes and odors are of a more serious nature or occur regularly, the application of activated carbon prior to sedimentation seems to be desirable.

In some cases it has been found that greater efficiency in removal of tastes and odors is accomplished when the carbon is applied to the settled water entering the filters. Conditions, which would seem to justify this point of application, are mild tastes and odors; tastes and odors of a periodic nature, or severe tastes which come up quickly but are discovered in time to permit correction at this point. Heavy dosages of carbon cannot be applied directly to the filters without adversely affecting the filter runs. Consequently, if high dosages of carbon are necessary to correct the taste and odor condition, it is advisable to apply the carbon prior to or during coagulation, or to utilize a split dosage; namely, both to the filter influent and to the raw water.

Dosages and Costs of Treatment

Because of the varying types and concentrations of taste and odor producing substances in water, it is impossible to predict the quantity of activated carbon necessary to correct an individual condition. Experiences have shown that dosages may vary from 1 lb. per million gallons to as high as 2,000 lbs. per million gallons. Extremely high dosages of activated carbons are usually required for only short durations of time and particularly on types of odors which are rather difficult to remove. Based on average taste and odor conditions, a dosage of 20 to 50 lbs. per million gallons is sufficient to insure delivery of palatable water. It has been calculated that the average cost of activated carbon would represent only approximately 3c per capita per year.

Threshold Odor Test

As a means of determining the degree of palatability of a water, the threshold odor test was developed by Charles Spaulding of Springfield, Illinois. In this test odors are compared against odor-free water in such a way that a definite number, measuring the individual intensity, is secured. By means of the threshold odor test it is possible in water works practice to pre-determine fairly accurately the quantity of activated carbon necessary for treatment in order to furnish a palatable supply to the consumers. As a result many plants have adopted the threshold odor test as a routine method of procedure on samples of water taken throughout the entire plant.

The threshold odor test has now been developed to such a point that with proper care and precision it can be utilized as a means of evaluating various activated carbons. Thus, with this method available, water works operators can assure themselves that they are purchasing that quality of activated carbon which will most economically remove tastes and odors from their individual supply.

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* A Division of the West Va. Pulp and Paper Co.
[1] John R. Baylis, Elimination of Taste and Odor in Water—McGraw-Hill Book Company—1935.

CONTROL OF ALGAE

By FRANK E. HALE, Ph.D.

Director of Laboratories, Dept .of Water Supply, New York City.

Knowledge of microscopic organisms and their control is one of the more important aspects of water supply practices. Chief amongst agents utilized in algae control is copper sulphate, its application to reservoirs being known as "coppering."

The simplest manner of application is to drag burlap bags, containing about 50 pounds each, through the water by means of rowboats, taking a zigzag course so as to triangulate the surface of the water. Wind, waves, diffusion and gravity admix the streaks of treated water with the remainder. Crude as this method is, it has been found very effective. But it is essential that the chemical be well distributed.

[Recently there has been effectively used by the Los Angeles Water Department a mechanical broadcasting device on the rear of a launch. It distributes pulverized copper-sulphate over the water surface in a manner equivalent to that used in broadcasting fine grass seed. This method reaches shallow shore-line areas most effectively. See Jour. Review, Feby., 1936.]

The reservoir should be partitioned into arms by land sights and the capacity, in million gallons for total depth, calculated for each area so that dosage may be correctly apportioned. In the case of organisms predominating in the upper water, dosage may be calculated on the upper 20-30 feet only. About 3,000 pounds a day may be distributed by a single launch in favorable weather.

Calculation of the volume of a body of water is not difficult. Two formulas should be kept in mind:

One cubic foot contains 7½ gallons.

One gallon of water weighs 8⅓ pounds.

Estimate the area in square feet. Estimate the average depth in feet by soundings. Multiply the two for cubic feet. Multiply cubic feet by 7½ to find gallons and express in million gallons. In the table of treatment which follows one column reads directly in pounds of copper sulphate per million gallons of water to apply for each genus of organisms.

To calculate amount of copper sulphate needed from "Parts per million" column multiply million gallons by 8⅓ to obtain million pounds of water. Multiply this figure by the amount shown in the column headed "Parts per million."

Two formulas are helpful to bear in mind:

1 pound per million gallons = 0.12 part per million.

1.0 part per million = 8⅓ pounds per million gallons.

Copper sulphate may be fed to an aqueduct by continuous dry-feed to destroy organisms feeding from one reservoir to another. The effective dosage is identical with that employed in open reservoirs by the launch method.

Another frequently employed method of continuous feed of copper sulphate is by solution feed. On a small scale a wooden bucket may be suspended in the flowing water so arranged that its depth of submersion may be varied. A small hole in the bottom of the bucket admits the water. The bucket is filled with copper sulphate and a definite amount added once or twice a day and the depth of submersion regulated so as to dissolve the determined quantity each day.

Three to four hundred pounds per day may be fed by the barrel arrangement shown. By this equipment the chemical is applied as a saturated solution and the application is very uniform. The barrel is kept constantly full of water from a supply controlled by a float valve with glass ball. From the bottom of the barrel, through rubber, glass and copper tubing, the solution is discharged to the water at the most turbulent point. The flow is regulated by a pinch-cock. The barrel sets on a scale so that the weight of chemical delivered may be checked. The water consumed varies with temperature and other conditions from about 1¼ to 2½ gallons per pound of chemical dissolved.

Copper sulphate is very soluble in water. The following table may be useful in feed regulations at various water temperatures:

SOLUBILITY OF COPPER SULPHATE

Temperature: °C.	°F.	Pounds of Copper Sulphate Crystals ($CuSO_4 . 5H_2O$) Per 100 lbs. solution	Per 100 gallons water
0	32	19.5	126.0
10	50	23.1	226.8
20	68	26.9	269.4
25	77	28.9	296.1
30	86	31.3	326.1
40	104	35.2	371.1
50	122	39.1	433.7
60	140	44.5	521.3
80	176	55.5	717.2

Spraying with strong copper sulphate solution is advantageous in some instances, *e.g.,* in shallow bays and on floating masses of certain organisms. For this purpose a spray pump or equipment such as is used with insecticides for trees is available. [An alternate procedure is that used by Los Angeles to mechanically broadcast the pulverized sulphate previously mentioned.—Ed.]

Walls of basins have been sprayed for growths such as Spirogyra, using a 5 per cent solution.

Experience differs with waters of different composition, with temperature, and with amount of organisms present as to the right dosage to apply for each organism. About twice as much chemical is required in winter as in summer. It is a waste of chemical to apply an insufficient amount. If a smaller dosage fails, the entire larger dosage must be applied at one time. The water usually clears within three to four days when the correct quantity has been applied. [See Dosage Tables.] Weeds in general are not killed by copper sulphate. Sometimes fish are killed, but rarely in quantity. The following table indicates the susceptibility of fish to the chemical:

LIMITING SAFE DOSAGE OF COPPER SULPHATE FOR FISH

Fish	Parts per million	Pounds per million gallons
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Gold Fish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.35	11.1
Black Bass	2.00	16.6

Chlorine Treatment

Chlorination is the most valuable adjunct to copper sulphate in control of microscopic organisms. In the first place it helps destroy the odors set free by the copper sulphate treatment. In the second place it destroys many *genera,* in several instances the very ones least affected by copper sulphate.

The use of chlorine in increased dosage has slowly been extended not only to destroy organisms but also the distasteful oils. Experience to date indicates that with soft waters the following effects have been noted:

EFFECTIVE CHLORINE DOSAGES

Organisms Units per cc.	Chlorine ppm. Dose	Residual	Effect— Org. destroyed	Taste destroyed
Synura 1—25	0.3	.05-.10	Yes	Yes
Synura 50—100	0.5-0.7	.20	Yes	Yes
Synura 200	0.7-0.9	.30	Yes	Yes
Uroglena 2,000	0.5	.10	Yes	Yes
Uroglena 6,000	0.5	.10	Yes	No
Dinobryon 500	0.5	.10	Yes	Yes
Asterionella 1,350	0.7	.20	Yes (50%)	No
Aphanizomenon 1,500	0.7-0.8	.20-.25	Yes (50%)	No

Prechlorination with high dosage, 1 ppm. and higher, is employed now quite extensively in conjunction with filtration to destroy or prevent growth of microscopic organisms in sedimentation and reaction basins and lessen their interference with filtration. Longer filter runs are obtained in addition to lightening the bacterial load upon the filters.

Miscellaneous Data. Cyclotella has been destroyed by dosage of 1 ppm. *Crenothrix* is another troublesome organism which is readily controlled by chlorine or chloramine in dosage of 0.5 ppm. Chlorine in dosage of 0.33 ppm. has readily controlled or prevented formation of jelly masses or fungus slime in well supplies and in mains and prevented clogging of condensers.

Crustacea, such as *Cyclops* and *Daphnia,* have been controlled on occasions. *Daphnia,* red variety, has been controlled with 1 ppm. chlorine and *Cyclops* with 3 ppm. chlorine.

The following table contains data brought up to date on dosages of copper sulphate and dosages of chlorine required for microscopic organisms, including also odors and tastes produced. It is based on published data and personal experience.

CHEMICALS REQUIRED FOR CONTROL OF DIFFERENT GENERA*

Organisms—Odor:	Copper Sulphate[1] Parts per million	Copper Sulphate[1] Pounds per mil. gals.	Chlorine ppm.
Diatomaceae:			
Asterionella‡	0.12*-0.20*	1.0-1.7	0.5*-1.0*
Aromatic, geranium, fishy			
Cyclotella†‡			1.0
Faintly aromatic			
Diatoma†			
Faintly aromatic			
Fragilaria†	0.25	2.1	
Melosira†‡§	0.20*	1.7	2.0
Meridion			
Aromatic			
Navicula†	0.07	0.6	
Nitzchia‡	0.50	4.2	
Synedra†‡	0.36*-0.50*	3.0-4.2	1.0
Earthy			
Stephanodiscus	0.33	2.8	
Tabellaria‡	0.12*-0.50*	1.0-4.2	0.5*-1.0
Aromatic, geranium, fishy			
Chlorophyceae:			
Cladophora†	0.50	4.2	
Closterium	0.17	1.4	
Cœlastrum†	0.05-0.33	0.4-2.8	
Confervа†	0.25	2.1	
Desmidium	2.00	16.6	
Dictyosphærium‡			0.5*-1.0
Grassy, nasturtium, fishy			
Draparnaldia	0.33	2.8	
Eudorina	10.00	83.0	
Faintly fishy			
Entomophora	0.50	4.2	
Glœocystis			
Offensive			
Hydrodictyon†	0.10	0.08	
Very offensive			
Microspora	0.40	3.3	
Palmella	2.00	16.6	
Pandorina	10.00	83.0	
Faintly fishy			
Protococcus			1.0
Raphidium	1.00	8.3	
Scenedesmus	1.00*	8.3	
Spirogyra†	0.12	1.0	0.7-1.5
Staurastrum	1.50	12.5	
Tetrastrum			1.0
Ulothrix	0.20*	1.7	
Volvox‡	0.25	2.1	0.3*-1.0
Fishy			
Zygnema	0.50	4.2	
Cyanophyceae:			
Anabæna‡	0.12*	1.0	0.5*-1.0
Moldy, grassy, vile			
Aphanizomenon‡	0.12-0.50*	1.0-4.2	0.5*-1.0*
Moldy, grassy, vile			
Clathrocystis	0.12*-0.25*	1.0-2.1	0.5*-1.0
Sweet grassy, vile			
Cœlosphærium‡	0.20*-0.33	1.7-2.8	0.5*-1.0
Sweet grassy			
Cylindrospermum	0.12	1.0	
Grassy			
Microcystis	0.20	1.7	
Oscillaria†	0.20-0.50*	1.7-4.2	1.1
Rivularia			
Moldy, grassy			
Protozoa:			
Bursaria			
Irish moss, salt marsh, fishy			
Ceratium†‡	0.33	2.8	0.3*-1.0
Fishy, vile, (rusty brown color)			
Chlamydomonas	0.50-1.0	4.2-8.3	
Cryptomonas	0.50	4.2	
Candied violets			
Dinobryon‡	0.18*	1.5	0.3*-1.0
Aromatic, violets, fishy			
Endamœba histolytica (cysts)			25.0-100.0
Euglena	0.50	4.2	
Glenodinium	0.50*	4.2	
Fishy			
Mallomonas	0.50	4.2	
Aromatic, violets, fishy			
Peridinium	0.50*-2.00	4.2-16.6	
Fishy, like clam-shells			
Synura‡	0.12*-0.25	1.0-2.1	0.3*-1.0
Cucumber, muskmelon, fishy, bitter taste			
Uroglena‡	0.05*-0.20*	0.4-1.6	0.3*-1.0
Fishy, oily, cod-liver oil taste			
Crustacea:			
Cyclops†‡§			1.0 -3.0
Daphnia†‡§	2.00	16.6	1.0 -3.0
Schizomycetes:			
Beggiatoa†	5.00	41.5	
Very offensive decayed			
Cladothrix	0.20	1.7	
Crenothrix†‡	0.33 -0.5*	2.8-4.2	0.5*
Very offensive decayed, medicinal with chlorine			
Leptothrix†			
Sphaerotilis, natans†	0.40	3.3	
Very offensive decayed			
Spirophyllum†			0.25*
Thiothrix†‡			0.5*-1.0
Fungus:			
Achlya			0.6*
Leptomitus	0.40	3.3	
Saprolegnia†	0.18	1.5	
Miscellaneous:			
Chara†	0.10 -0.50	0.8-4.2	
Nitella flexilis†	0.10 -0.18*	0.8-1.5	
Objectionable			
Potamogeton†	0.30 -0.80	2.5-6.7	
Nais†			1.0*
Blood worm, chironomus†			15.0-50.0
Blood worm, gnats			3.0

The organisms where odors are expressed have been in sufficient quantity at one time or another to cause the characteristic odor.

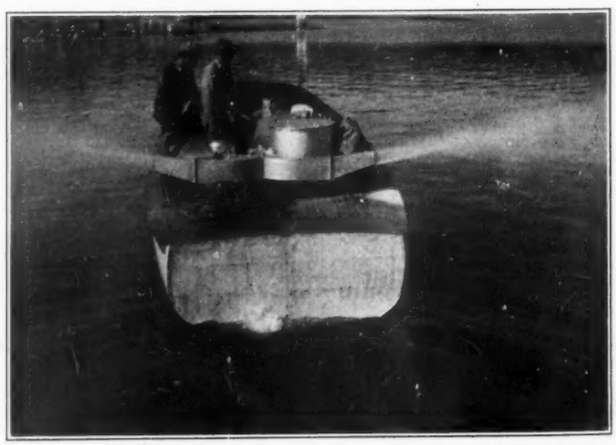
[1]The quality of water (hard or soft) and temperature has a decided influence on the requisite copper dosage. The harder the water, and the colder, the higher the dosage required. To under-treat is a waste of chemical and further—the whole dosage must be applied at one operation.

*Dosage successful in New York City's supplies.

†These organisms have caused trouble other than odor.

‡These organisms have been affected by chlorine producing characteristic odor and in many cases controlled by dosage ranging from 0.3 to 3 ppm., depending largely on amount of organisms.

§Controlled by excess caustic lime, 5 ppm., in the case of diatoms (48 hrs.).



Los Angeles' Improved Dry-Feed Coppering Machines Used in Algae Control, Surface Applications Have Proved More Economical and Effective. All Shallow Areas Are Reached Easily.

COPPER AND HEALTH

The effect of copper on health is a subject of such importance to all users of copper and brass and copper sulphate for algae control, that the conclusions in an article read before The New England Water Works Association* are given below:

1. The copper content of domestic drinking water after passing through copper or brass pipe or tubing, even if a slight amount of copper is taken into solution, is not harmful to health. It may indeed be beneficial.

2. All water supplies intended for domestic use after passing through a proper installation of copper or brass pipe or tubing will contain but a small percentage of the permissible copper content, if any at all.

3. The permissible copper content of domestic water based on a consumption of one gallon of water a day should apparently not be greater than 20 p.p.m.

4. It is unlikely that health will be injured by copper because, where the copper content is above 5 p.p.m., the taste of the water will generally be so disagreeable that it will be virtually impossible to drink it.

5. No anxiety need be felt about a proper installation of copper or brass pipe or tubing, because it has been shown that with acid water having a pH value of about 6.5, the copper content is generally only about 0.5 p.p.m., even after standing in the pipe lines for an appreciable length of time.

6. The treatment of reservoirs with copper sulphate to rid them of undesirable microscopic growths has no injurious effect on health.

*Journal N. E. W. W. A., 44: 4, December, 1930.

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
Dry Chemical Feed Devices, etc.
NEWARK, NEW JERSEY

"The Only Safe Water Is a Sterilized Water"

Atlanta	Chicago	Detroit	Kansas City	Minneapolis	Roanoke
Boston	Cleveland	Greensboro	Knoxville	Oklahoma City	San Francisco
Bridgeport	Columbus	Houston	Lexington	Omaha	Seattle
Buffalo	Dallas	Indianapolis	Los Angeles	Philadelphia	St. Louis
Charlotte	Denver	Jacksonville	Madison	Pittsburgh	Syracuse
					Washington, D. C.

WALLACE & TIERNAN, Ltd., Toronto, Canada **WALLACE & TIERNAN, Ltd., Montreal, Canada**
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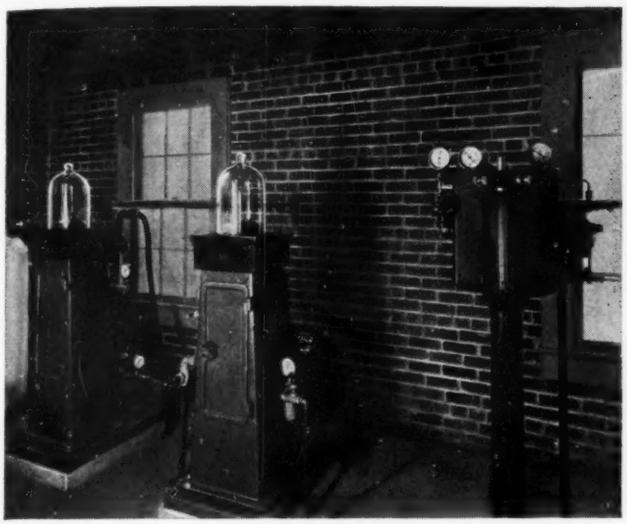


Two Visible Vacuum Chlorinators—1 Manual and 1 Automatic—and Automatic Ammoniator installed at Greenville, S. C.

CHLORINATION

Chlorination is the accepted standard of sterilization in water works practice. Costing only a few cents per million gallons of water treated, easily applied, simply controlled and positive in bactericidal action, it has contributed more than any other one measure in reducing America's typhoid death rate from 30 per 100,000 to less than 3. Whether the source of supply is polluted surface water or clear, sparkling well or spring, its purity should be insured by the certain protection chlorination provides. Over 23,000 units of Wallace & Tiernan equipment in all parts of the world attest the universal accord with which chlorination and W&T Chlorinators are accepted.

TASTE AND ODOR CONTROL WITH BREAK-POINT CHLORINATION

Chlorination to the BREAK-POINT is a convenient way of describing the phenomenon produced in many waters when very much larger rates of chlorine are applied than has heretofore been customary standard practice. Hundreds of tests have shown that with most waters there is a rate of chlorine application that will be sufficient to break down taste producing organic matter and at the same time leave residual chlorine at a minimum.

The results which have been secured by BREAK-POINT Chlorination in a large number of instances have been so spectacular as to be almost unbelievable. Tastes and odors so severe as to bring an avalanche of complaints from consumers have been eliminated.

AMMONIATION

The ammonia-chlorine process has proved itself to be a valuable aid in the solution of many water works operating problems. Chloramine—formed by the combination of chlorine and ammonia—while somewhat slower in bactericidal action than chlorine, offers many distinct advantages particularly on small gravity water supplies of widely fluctuating flows.

Chloramine eliminates chlorophenol tastes and because of its more persistent residual, prevents aftergrowths in the distribution system . . . offers more effective algae control and prevents subsequent pollution by carrying sterilizing action all the way to the consumer's tap.

APPLICATION OF DRY CHEMICALS

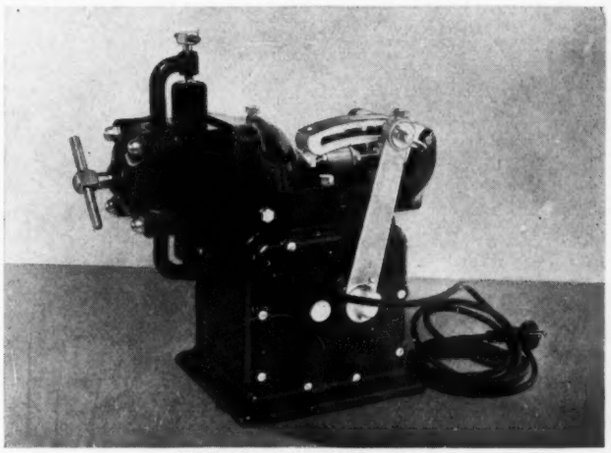
The development of dry chemical application has been of great value in both sanitary and industrial fields. Difficulties from leaking tanks, corroded constant level boxes, clogged orifices, broken valves, and all the untidiness and disagreeable features incident to solution feed systems are eliminated. Of particular advantage in filter plants for applying alum, lime, soda ash or carbon, dry chemical application effects large savings in labor and materials.

CHEMICAL SOLUTION FEEDER

Some chemicals such as hypochlorites are readily available in solution form and present problems in dry feed which make it desirable to handle them in solution form.

The W&T Chemical Solution Feeder is designed to feed chemical solutions such as sterilizing agents, coagulants or corrosion inhibitors with accuracy and dependability.

Type MOF Dry Chemical Feeder for accurate control of Alum, Lime or Activated Carbon.



W&T Chemical Solution Feeder

W&T EQUIPMENT

Complete in both arrangement and capacity, the W&T line of Chlorinators, Ammoniators, Dry Chemical Feeders and chemical solution feeders is designed to meet every water works requirement. Long life, low maintenance and utmost accuracy and dependability characterize each installation, reinforced by the services of a nationwide organization operating from 29 Sales and Service Headquarters. The recommendation of W&T field representatives involves no obligation. Feel free to call on them.

Current literature on the many phases of chlorination, ammoniation and chemical feed is available on request.

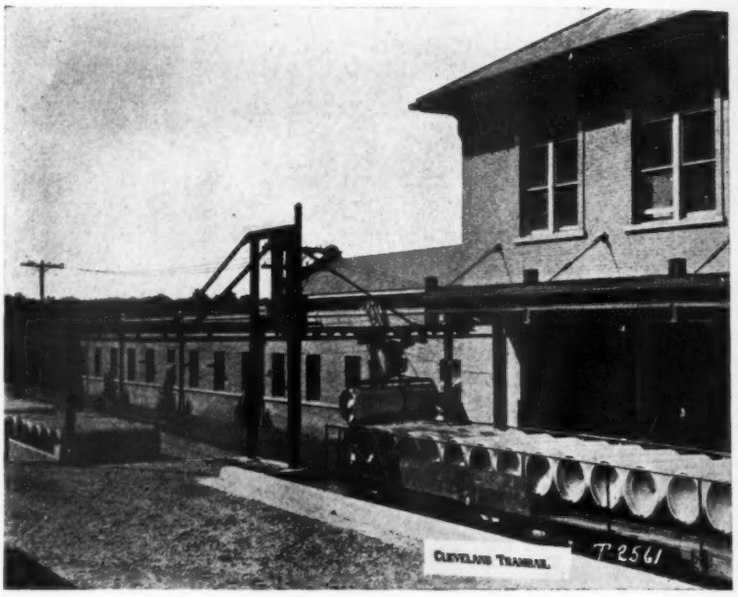
PENNSYLVANIA SALT MANUFACTURING COMPANY

WIDENER BUILDING, PHILADELPHIA, PA.

NEW YORK • CHICAGO • ST. LOUIS • PITTSBURGH • TACOMA • WYANDOTTE

• LIQUID CHLORINE

A clear amber-colored liquid approximately one and one-half times heavier than water. Supplied in steel containers which are under pressure at temperatures exceeding 30.1° F. It is only slightly soluble in water, its maximum solubility in distilled water being approximately 1% at 49.2° F. When pressure is released, liquid chlorine volatilizes into a greenish-yellow gas which is approximately two and one-half times heavier than air. It is non-inflammable, non-explosive, and a non-conductor of electricity. Generally, in the absence of moisture it is not corrosive to common metals at temperatures below 212° F. Moist chlorine or aqueous solutions of chlorine require special equipment materials for handling.



Of the various agents for sterilizing water supplies, chlorine has proved to be the most efficacious, flexible, and economical. Under certain conditions it has the additional advantages of a sludge stabilizer, of a taste and odor eliminator, of a precipitating aid, as well as of a prolonged sterilizing agent. The quantity of chlorine required in water purification processes depends upon the quality of water, the point of application, and the object desired. Chlorine is also widely used in sewage treatment for disinfection, for B.O.D. reduction, and for odor control.

Liquid Chlorine is supplied in seamless steel cylinders in sizes ranging from 10-lb. net to 150-lb. net. They comply with every requirement of the Interstate Commerce Commission concerning specifications, retesting, loading, and maintenance of cylinders for transporting liquid chlorine. It is also supplied in multiple-unit tank cars holding 15 containers of one ton each, and in single-unit tank cars of two sizes: 32,000 and 60,000-lb. chlorine respectively.

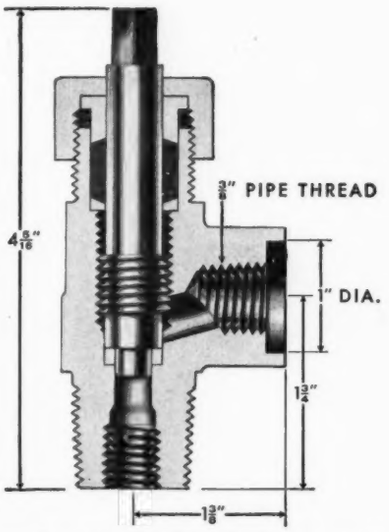
• PERCHLORON

A supertest calcium hypochlorite, containing more than 70% available chlorine. It is a free-flowing, fine, white, dry powder quite different from ordinary bleaching powder—being concentrated, stable, and much less hygroscopic. It weighs approximately 55 lb. per cubic foot, and 75% will pass an 80-mesh screen. Perchloron maintains 97% of its active ingredient for a 12-month period when stored in tight containers. It is quickly soluble in water. It is used as a second line of defense in water purification in time of emergency, when normal supplies of liquid chlorine may be temporarily cut off. Used for sterilizing new mains, as well as clear wells, and filters, and also in sewage treatment. Widely used by swimming pools to control and combat althlete's foot, by means of hypochlorite footbaths. It is supplied in handy-sized cans equipped with Kork-N-Seal covers —9 cans to the case. Also in 75-lb. drums.

• AMMONIA, Anhydrous

A colorless liquid which, at 70° F. is .61 times as heavy as water, weighing 38.0 lb. per cubic foot. When pressure is released, it volatilizes to a colorless gas of penetrating odor, which is 0.597 times as heavy as air at standard conditions. Dry ammonia is not corrosive to the common metals, but moist ammonia attacks copper and all of its alloys, hence iron pipe and fittings are always recommended. Ammonia is exceedingly soluble in water. At 32° F. 1150 volumes of ammonia will dissolve in 1 volume of water, or 47.3% by weight.

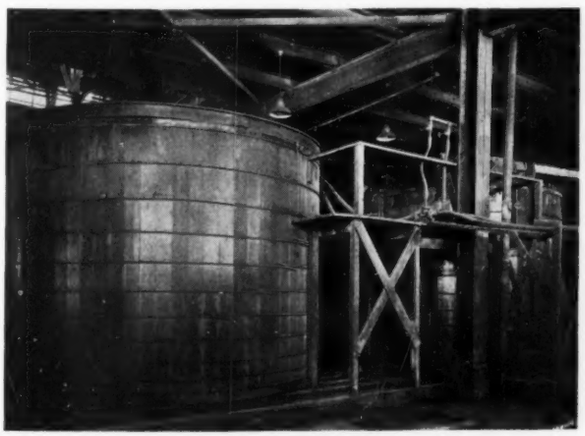
The practical advantages of this characteristic of ammonia are observed in the employment of dry feed ammoniators in water works, and the utilization of showers for controlling serious leaks. It is used in the chloramine process, in which ammonia is applied in



conjunction with chlorine to prevent the formation of chlorinous, phenolic, or medicinal taste; and for stabilizing or prolonging the sterilization action of chlorine. Ratios of ammonia to chlorine varying from 1:1 to 1:12 have been effective, while the points of application have ranged over the entire purification process. In order to prevent taste intensification, the ammonia must be applied before the chlorine. The anhydrous ammonia produced by this Company is supplied in new and improved containers which are far easier to handle and store. They are seamless drawn cylinders of special steel, exceedingly light and strong. Gas may be withdrawn with the cylinders placed in an upright position on a scale for weighing, or in a horizontal position if desired.

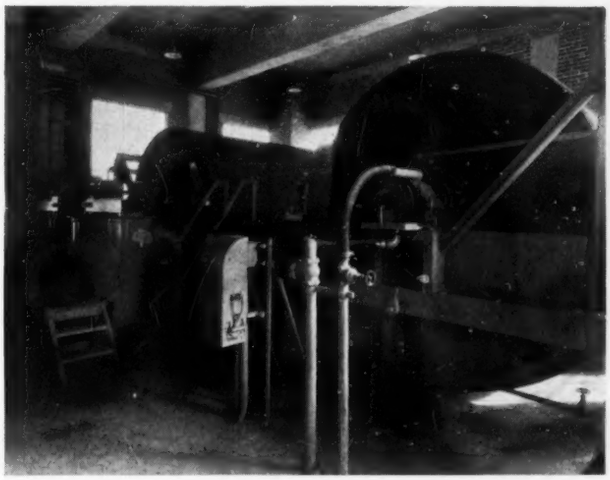
● FILTER ALUM (Sulphate of Alumina)

The principal coagulant used in water purification. Sold in all quantities from a single bag, or barrel, to carload lots, both packages and in bulk. Bags and barrels are paper lined as a protection against atmospheric moisture.



● FERRIC CHLORIDE

In liquid form it is an aqueous solution the concentration of which is governed by the outside temperature, varying from 39% $FeCl_3$ in extremely cold weather to 45% in extremely hot weather. Also available in an anhydrous form which is water-free and as near to 100% $FeCl_3$ as permitted by the impurities in the steel scrap from which it is made. Ferric chloride is a positive coagulant, producing clean-cut flocculation in economical doses. In most localities, depending upon shipping costs, ferric chloride offers tremendous economies over alum. In liquid form it is shipped in rubberlined tank cars holding 8,000 gallons and averaging 40,000 lb. of dissolved $FeCl_3$ per car. In anhydrous form it is shipped in non-returnable steel drums holding 150 lb. and 400 lb. of material respectively.



● SODIUM ALUMINATE

An alkaline compound of alumina and caustic soda which is used for softening water, and as a combined coagulant and softening agent. It is used most effectively on those waters requiring an alkali with the alum. It is usually shipped in thin steel non-returnable drums of 108 and 425 gross pounds having a net weight of 100 and 400 lb. each. 100-lb. moistureproof burlap bags are also commonly used.

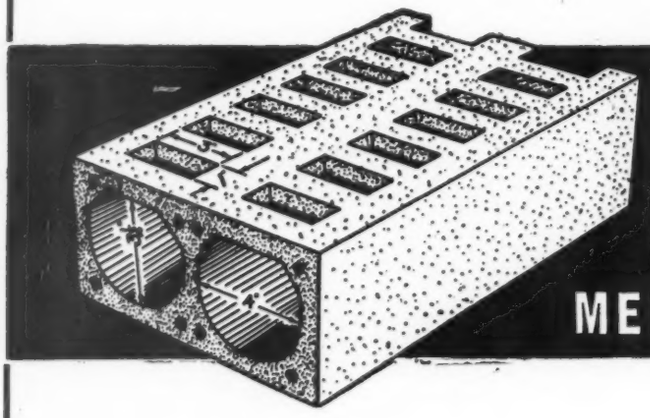
● CHLORIDE OF LIME, and CAUSTIC SODA

are two other chemicals made by this Company which are used in water purification and sewage treatment. We will gladly supply further detailed information, and our technical staff is always available to assist you.

THE BOWERSTON SHALE CO., Bowerston, Ohio
AYER-McCAREL-REAGAN CLAY CO., Brazil, Indiana
LICENSED MANUFACTURERS

A Trickling Filter Is As Efficient As Its Underdrain System

How



"ARMCRE"
FILTER BOTTOM BLOCKS MEET THE REQUIREMENTS

Hundreds of Installations . . .

"ARMCRE" Filter Bottom Blocks have been installed in hundreds of Sewage Treatment plants and below are some of the reasons the engineers specified it:

When you buy Armcre Filter Bottom Blocks you buy a complete floor as the following fittings are kept in stock at all times: one-quarter, one-half and three-quarter length blocks; fifteen, thirty and forty-five degree angle cuts; cover blocks for covering drainage channels and cover blocks with holes for aeration feature at edge of beds; also reducers which solve the double problem of making the underdrain system accessible for quick inspection, flushing or cleaning without weakening the masonry wall, as shown on our detail sheet.

The Design assures adequate air supply, the area of the ducts is 25 square inches per block, 50% of its cross section! Each block has 14 openings, aggregating 42 square inches, allowing air to circulate freely and maintain aerobic condition. Armcre blocks are made of the best deaired Vitrified shale and fire clay ware. They are smooth on the entire inner surfaces of the ducts, and solids by adhesion or absorption do not accumulate.

Exact alignment and grade are made easy by the longitudinal center line scored on each block so they can be laid in an exact vertical plane along its entire axis.

Write and we will be glad to send you a list of installations including the names of the designing engineers and a detailed description of "Armcre" Filter Blocks.

PART II. SEWERAGE

Whereas, this section is devoted almost exclusively to Sewerage, it was not possible to segregate material, which pertains to Water as well as Sewage, except at the expense of duplication.

The Water Works Section contains considerable material of direct bearing on Sewerage.

SEWERAGE FINANCING

Modern Methods and Experience

By W. F. TEMPEST, Engineer*

Municipal Bureau, Portland Cement Association, Chicago

PRACTICAL methods of financing sewerage improvements are urgently needed and eagerly sought. From experience and study of modern methods of sewerage financing, the merits of sewer rentals and sewer revenue bonds are being brought into sharp focus. There is immediate need for more factual data from municipalities which have had actual experience in formulating rate schedules for service charges and in the application of this method to financing with sewer revenue bonds. Experiences as outlined by Robert A. Allton of Columbus, in earlier issues of WATER WORKS & SEWERAGE, and by others, are of timely interest and should be of value to municipalities seeking the most practicable means of financing the needed facilities.

Enabling Acts

Although enabling acts for financing with sewer rentals and revenue bonds have now been passed in thirty-four states, the emergency nature of some of the acts makes necessary some clarifying amendments to broaden the scope of the borrowing power of municipalities. In a few cases the acts are not permanent but in those states consideration is being given to revision and passage of legislation that will be permanent.

Full appreciation of the benefits of such legislation is not yet general and even in many states with adequate legislative provisions, municipalities have failed to take advantage of it.

Sewer Rental May Be Charged Without an Enabling Act

It is desirable to have a clear definition of the terms "Sewer Rentals" and "Revenue Bonds." Sewer rental is a service charge made for use ofthe sewerage system and the treatment works. In some cases it is applied only to the treatment works, but its application to the entire sewerage system is becoming more general. The charges are usually made monthly or quarterly and paid by the user, not necessarily the owner of the property served. The revenue from such service charges is used to pay for operation and debt service in whole or in part.

CITY OF EDWARDSVILLE, ILL.
SEWER SERVICE RENTAL

DOMESTIC RATES (NET PER MONTH)	
Service Connection Minimum	$ .75
Up to 12,000 Gallons	.75
12,000 to 22,000 Gallons	1.25
22,000 to 32,000 Gallons	1.50

COMMERCIAL RATES (NET PER MONTH)	
Service Connection Minimum	$1.50
Up to 15,000 Gallons	1.50
15,000 to 25,000 Gallons	1.75
25,000 to 35,000 Gallons	2.25
35,000 to 45,000 Gallons	3.25
45,000 to 100,000 Gallons	5.00

FLAT RATES (As Per City Ordinance No. 604)

Bills are payable to City of Edwardsville at City Hall. EDWARD H. POOS, City Clerk.

Note: If bill is not paid within 10 days after date below a 10 per cent penalty is added to net amount.

Date of this bill .....

Rental for this month .....

Amount forwarded .....

TOTAL AMOUNT .....

AMOUNT PAID .....

DATE OF THIS BILL .....

Note: When paying by mail please enclose this stub.

In Edwardsville, Illinois, this separate form of bill, printed on the back of a penny post card, is mailed to customers each month.

The sewer rental method may, in fact, be used to retire general tax obligation bonds, as described by Robert A. Allton in his article in this magazine discussing sewer rentals in Columbus, Ohio; or it may be used to retire other certificates of indebtedness. Its use is not confined to revenue bond financing and may be applied in states *without* enabling legislation for revenue bonds.

Revenue bonds are considered a form of municipal bond issued by a political subdivision for the purpose of constructing, acquiring or improving revenue producing works such as sewerage, sewage disposal and water works. Payment of such bonds depends entirely upon the revenue of the utility. The issuance of revenue bonds does not add to the bonded indebtedness of a municipality within the meaning of constitutional or statutory debt limitations. It is, therefore, possible for a municipality to finance improvements by this method when it would otherwise be impossible because of stringent limitations. However, as pointed out by prominent municipal bond houses, revenue bond financing should not be considered an easy entrance into debt for the improvident municipality. Although the full faith and credit of the political subdivision is not directly pledged as security for revenue bonds, the financial standing and debt history of the municipality will have an important bearing on the value and marketability of the bonds.

Referendum and Education

In many states it is possible to issue revenue bonds without a vote of the people. All that is necesary is a satisfactory bond ordinance passed by the council. Many have found it desirable, however, to ask for a referendum even though not legally required. When this is done it is important that the public be fully informed regarding the need for the improvement, its cost and the proposed service charge. Lack of an honest and intelligent publicity campaign may result in the defeat of a bond issue for an urgently needed improvement. An educational campaign is desirable regardless of whether a referendum is held or not. Publication of facts about the improvement and benefits to the municipality will react in many ways favorable to the city. General statements also will aid in giving the public, and especially investors, simple facts from which they gain some appreciation of the character of the municipality. Such facts will include growth of the community, industrial, business and residential, improvement programs, administration, debt control, tax rates, collections, particularly favorable experience in water and sewer bill collections.

Billing and Collection Experiences

Reports assembled recently from municipalities in 17 different states showed 92 cities charging sewer rentals and in only two or three were there any difficulties reported with collections. Even so, the average uncollected balance of those reporting delinquencies was not as much as 5 per cent. A few reported mild protests on the first bills but these soon disappeared. In one case delinquencies were high due to protests at not having a referendum, and in another case there was disagreement between owners and renters on who should pay.

The billing method most preferred seems to be the monthly basis, and 50 per cent of the cities for which information was

* The author is Secretary of the Committee on Joint Administration and Collection of Water and Sewer Charges of the Am. Water Wks. Ass'n.

Date ..... 193...

CITY OF MITCHELL — DEPARTMENT OF WATERWORKS
WATER BILL

Meter Reading at End of Period - - - - .....
Meter Reading at Beginning of Period - - .....
Gallons Water Consumed ..... Amount $.....

No deductions made on account of leaks or water wasted.

Unpaid Previous Balance - $.....
Total Due Water Dept. - $.....

PLEASE NOTE
MINIMUM CHARGES
WATER—
Per Mo. $1.00
(2500 Gals.)
SEWER—
Per Mo. .....
Bills are payable for each month's service during the first 10 days of the following month. A charge of $1 is made for reestablishing services disconnected for non-payment.

CITY OF MITCHELL — DEPARTMENT OF SANITATION
SEWER BILL

Total Gals. Water Used ..... Amount $.....
Unpaid Previous Balance $.....
Total Amount Due for Sewer Service $.....
TOTAL AMOUNT DUE—WATER AND SEWER SERVICES $.....
PLEASE BRING THIS CARD WHEN MAKING PAYMENT

City of Mitchell
WATER BILL
This Month $.....
Arrears - $.....
Total Due
Water Dep. $.....

SEWER BILL
This Month $.....
Arrears - $.....
Total Due
Sewer Dep. $.....

Total Amount DUE $.....

Return This Stub when paid by check.

Mitchell, Indiana, sends out one billing card, but shows water and sewage charges separately.

tabulated send sewer rental bills out monthly, most of the others quarterly or semi-annually. Six cities in Pennsylvania and one in Virginia reported annual billing.

The Rate Basis

The rate basis for the service charge in most cases was on the metered water consumption. In general this is the simplest and most equitable. The rate schedule should in all cases bear a relation to the use of water, even though the charge is assessed as a flat rate. Also general benefits should be considered when the charge is made on the basis of the water meter readings. There is a direct benefit accruing to the property from sewerage improvements and it is recognized that the owner should pay a certain share of the cost of the improvement. This charge may be made against the owner when connection is made to the sewer. Determining a rate schedule will also involve consideration of the character of the different areas served, that is whether domestic, business or industrial, and the quality of the sewage. The proper schedule of charges will necessarily have to be worked out for each specific case, and the municipal officials should give every possible assistance to the engineer in establishing a fair rate basis which will subsequently be incorporated in the rate ordinance.

Legal Advice Important

The actual financing of the project should be discussed with a well recognized firm of bond attorneys and with bond houses specializing in municipal securities. Many bond houses now recognize the special merits of revenue issues and are steadily building up a market for sewer revenue bonds. With continued favorable experience with this type of bond its use should spread to a large number of municipalities in states having satisfactory legislation. So far the sewer revenue method of financing has been most popular in the mid-western states. It has been applied to a limited extent in some eastern states and a number of cities in the western and Pacific Coast states have shown a live interest and a desire to finance sewerage improvements with revenue bonds. No actual experience has yet been reported, however, from the far West.

Special Authorities Not Usually Necessary

In most cases where the sewer rental and revenue bond methods of financing have been used it has not been necessary to create new units of government. There is no basis for a fear that revenue financing will result in new overlapping units of government. It does, however, bring about a closer cooperation in the administration of the waterworks and sewerage divisions of the city. In this way it is possible to achieve economy, especially in billing and collections.

Where special "authorities" have been formed, peculiar conditions and circumstances were such as to make this form of administration the most advantageous. The unique quality and the high order of the executive work of these authorities where they were definitely needed has won the respect of those whom they serve and those with whom they deal. The formation of a separate corporation or "authority" is a device to be employed only under special conditions. Its general adoption is not necessary for a wide and successful use of the sewer rental method, or for the increased use of revenue bond financing.

It is to the best interests of all municipalities to give serious consideration to these sound methods of modern sewerage financing. This relatively new method of financing will be especially useful when federal grants for public works have been materially reduced. It will enable municipalities to obtain needed facilities otherwise impossible without disturbing their existing fiscal program. Therefore the "Sewer Rental" method of financing sewage disposal deserves the careful consideration and study by all concerned. With the trend in the direction of consolidation of water works and sewerage departments of municipalities, water works managers should be especially interested in the modern and scientific method of financing through sewer rental collections.

Exhibits and Illustrations

Now will be presented some illustrations of how the method is employed and typical exhibits of billing forms.

The following significant recommendations of the Investment Bankers' Association concerning Special Revenue Bonds are taken from an extract which appeared in the Commercial & Financial Chronicle:

"Special Revenue Bonds:

"Reference is made to a resolution adopted by the Board of Governors on May 11, 1937, that part of which outlining specifications is as follows:

"That advertisements or circulars describing revenue bonds shall clearly indicate the nature of the obligation.

"That the customary form of the ordinary municipal circular and advertisement be varied to prevent confusion in the mind of the casual or careless reader.

"That the type of obligation be described clearly in the caption and with prominence consistent with that accorded to the name of the municipality.

APRIL BILL
Payable on or Before April 30, 1938
Failure to Receive Bill Does Not Excuse Consumer so Net Amount WHEN PAYING AT OFFICE. Please Bring Entire Bill.
OFFICE HOURS—8:00 a. m. to 5:00 p. m. On the 20th of the month 8:00 a. m. to 12:00 M.
CLOSED ALL DAY SATURDAY AFTERNOON—If last day of month falls on Saturday, Sunday or a Holiday, Net Bill will be collected on the following business day.

CITY OF GRAND HAVEN
SEWAGE DISPOSAL DEPT.

Service Charge	Arrears

10 Per Cent Penalty Added after April 30, 1938

PAYABLE ON OR BEFORE APRIL 30, 1938
Sewage Disposal Dept.
WHEN PAYING BY MAIL ATTACH THIS STUB TO YOUR CHECK OR MONEY ORDER

Service Charge	Arrears

A separate bill is used by the Sewage Disposal Department of Grand Haven, Michigan. The rates, based on water meter readings, for quantity per quarter at monthly charge are as follows: Up to 5,000 *gals.,* $0.50; 6,000 *to* 10,000 *gals.,* $0.75; 11,000 *to* 15,000 *gals.,* $1.00; 16,000 *to* 20,000 *gals.,* $1.25; 21,000 *to* 25,000 *gals.,* $1.50; 26,000 *to* 50,000 *gals.,* $2.50; 51,000 *to* 100,000 *gals.,* $4.00; 101,000 *to* 200,000 *gals.,* $6.00; 201,000 *to* 500,000 *gals.,* $10.00; 501,000 *to* 1,000,000 *gals.,* $15,00; *over* 1,000,000 *gals.,* $25.00

"That priority of obligation, if any, be stated specifically.

"That the statement of assessed valuation, total debt, etc., if included, be given a secondary rather than a primary position.

"That in connection with such statement of assessed valuation, etc., a statement shall be made, and prominently displayed, to the effect that the assessed valuation reported is not subject to taxation for the payment of principal or interest of the bonds."

Bill for MUNICIPAL UTILITY SERVICE (Service of the Combined Waterworks and Sewerage System)
CITY OF ELMHURST, 132 Addison Ave., ELMHURST, ILLINOIS Tel. Elmhurst 1800

OFFICE HOURS: 8 A. M. TO 5 P. M.—WEDNESDAYS 8 A. M. TO 12 NOON

READING DATE FROM	READING DATE TO	METER READINGS PRESENT	METER READINGS PREVIOUS	WATER CUBIC FEET	QUANTITY CHARGE	GROSS BILL	Discount For Prompt Payment Only	PREVIOUS BILL UNPAID	TOTAL AMOUNT DUE
		SERVICE CHARGE (SEWAGE DISPOSAL) →							

QUANTITY CHARGE (Measured by Water delivered and based on one month's usage.)
Any portion of the
FIRST 4,000 Cubic Feet @ $2.25 per 1000 Cu. Ft.
NEXT 16,000 " @ 1.87½ "
" 60,000 " @ 1.50 "
All Additional " @ 1.12½ "
Minimum Quantity Charge .75 per Month

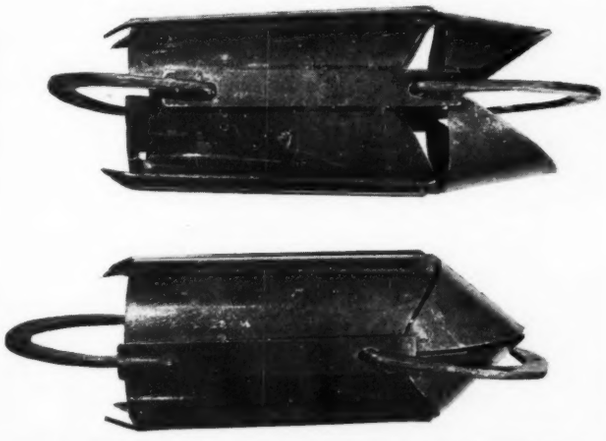
SERVICE CHARGE per month.
Single Family Residence $0.80
Duplex " " 1.60
Apartment and Office Bldgs. and similar class named in Ordinance, 40% of quantity charge.
For other classifications see Ordinance.

SAVE YOUR DISCOUNT—5% IF BILL IS PAID WITHIN 10 DAYS OF DATE. MAKE CHECKS PAYABLE TO CITY OF ELMHURST.

BILLS PAYABLE AT
CITY OFFICE, 132 ADDISON AVE YORK STATE BANK, 529 SO. YORK ST. HIERONYMUS DRUG STORE, 500 SPRING RD. OTTO'S GROCERY & MARKET, 675 W. ST. CHARLES RD.

One Form of Combined Bill for Water and Sewerage Utility Service Rendered Monthly
In this case the "Service Charge" for sewage disposal is on a simple fixed monthly basis, and is very nearly the same as the minimum "Quantity Charge" for water used.

OK Champion Bucket—Open and Closed



Mount Akron! Removed From One Akron, Ohio, Sewer with OK Champion Equipment

Champion Corporation
4714-38 Sheffield **Hammond, Indiana**

QUICK...

The velocity of 1,300,000 gallons in 24 hours through a 12 inch sewer is 2½ feet per second.

And that's just the speed of the

OK Champion Sewer Cleaning Bucket

as it goes through the sewers in normal operation. Never before has sewer cleaning been even half so important in your sanitary program. Many sewers are 30, 50 or more years old. They need a carbon cleaning and valve grinding job to run right again. Tons of cinders wash down from streets on which they were scattered for non-skid protection during the winter. Costly sewage disposal plants are designed to handle sewage—NOT dirt and debris.

Clean them at low cost with the latest tools. 3½, 5 or 7c per foot are average costs. Sand, roots, gravel, stones, sticks, junk or what have you are removed as easily as a power shovel excavates for a basement. Don't wait until you HAVE to do it. Make sewer cleaning a routine operation. Get on sewer cleaning before the clogged sewers become an epidemic—and a headache.

The OK Champion line is most complete. Motor power cleaners, hand power cleaners, buckets, sewer rods, and all accessories.

We will be glad to send you literature.

SEWER MAINTENANCE

Some Practices Developed from Experience

By C. GEORGE ANDERSEN, Superintendent
Dept. of Sewers and Sewage Disposal
Rockville Centre, Long Island

In the sewerage problems of today the treatment plant and types and design of sewers seem to take the lead. Now, when one considers the investment in sewer lines as the primary structure, providing an indispensable service in the removal and disposal of sewage, we are in general too negligent in the matter of maintenance and operation of sewers for the best interests of the public and efficient functioning of the treatment plant.

At Rockville Centre the writer, like many other men in charge of sewerage systems and sewage treatment, had his problems. The first was the effective and economical treatment of liquid and solids at the treatment works. Then, after catching up on this important phase of the cycle, in looking around it seemed important to face squarely the other sewerage investment amounting to four times as much,—namely, the sewers. In Rockville Centre we have not so many miles of sewers, nor very large ones, but those we have are as important to proper functioning of the entire system as though they were in a metropolis. The sizes range from 8 to 30 inches, and these sewers clog with roots, sand and many other materials.

Sewer Cleaning

Sewer cleaning being one of our problems, after our sewer lines are laid it becomes a necessity to maintain them in good working condition, and we might just as well lay out a program of routine cleaning and maintenance, rather than wait until trouble overtakes us. Continuing and repeated emergency calls, growing out of sewer stoppages, is very costly. In addition to extra expense there results many disgruntled taxpayers, inconvenienced by stoppages and put to added expense, due to their sewer lateral being plugged because of some backage in the main in the street.

Some Notes on Equipment and Its Effectiveness

For sewer cleaning and removal of roots, there are many types of equipment now available. Flexible steel sewer rods are a recent innovation in such equipment. These rods have an advantage in that the necessity for going down in manholes is eliminated. The rods are made up in three foot lengths, which coupled together make one complete flexible rod that is usually coiled between uses. Wood rods of five foot lengths (coupled together as they are being pushed into the sewer line) also continue in use to some extent. The wood rods, being more rigid than the steel rods, follow a straight line more successfully, but cannot be turned and forced to the extent that the new flexible steel rods can.

The "Turbine" type of sewer cleaning instrument is probably the most positive of all types made today. This device (adjustable to any diameter sewer) is a water powered rotating cutter. In employing the "Turbine", it is necessary to have two winches and cable to draw it through and back between manholes in the line, while the high speed rotating knife blades do a clean job of root cutting and scaping.

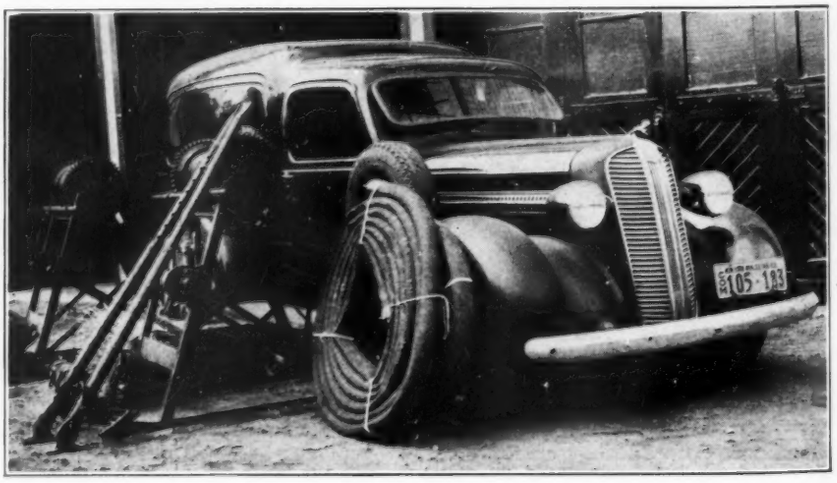
Rods of any kind, which can be used efficiently in making time and mileage when going over an entire sewer system as laid out in a program, are good up to a certain point such as the removal of small deposits and light root growths. On the tougher jobs, such as spots where knob roots have formed (see cut), a more positive applied type of equipment is required. In such cases it becomes necessary to use the "Turbine" cutter, or some similar tool, that will slowly but surely remove the obstruction if it is such as can be cut by steel.

I stress this point, because on one occasion a severe stoppage occurred in an eight inch line. Our Flexible sewer rods were first used, but could only give relief to the extent of four inches. That is, the four inch auger-head was the largest tool that could be forced through. The supposition in this case was that the trouble was caused by a broken spur, being replaced by a makeshift stack which extended into the sewer line. Many other suppositions also were expressed, but there is only one thing to do in a case like this (and such is good for experience)—dig it up. This was done and the trouble was, in fact, at a spur. The spur was not at fault, however, but through the joint preceding it a large root had entered. The question was, how to remove it. A hole was cut in the eight inch tile sewer line so that action of the available cutting tools could be observed as it was applied to the root. The root had formed a five finger knob on the top inside of the pipe (see cut). When the Flexible sewer rod with the auger used in eight inch line was applied to the root the tool just jumped back and had no effect. This satisfied me as to the necessity of having a positive applied sewer cleaning cutter, especially for clearing out those very deceiving *top* roots which cannot be removed by auger and do not stop sewage flow until they are definitely a menace in the sewer.

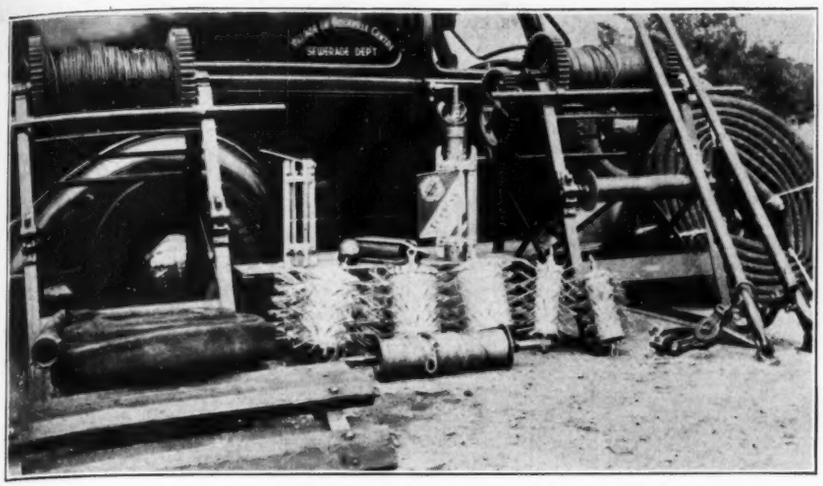
Sand and gravel which have built up around paper, roots and other matter in a sewer, are also a headache. We find that one cannot have *too much* equipment. And, we have also learned that in sewer maintenance different makes of equipment can be used in combination or in sequence to produce very efficient work. Take the case of sand; Flexible steel rods can be used to get an opening through the sand. This constitutes the first important step. Then a cable may be drawn through so as to draw a bullet or tool for loosening and liquifying sand stoppage. Thereafter, the Turbine flusher or cleaning buckets, whichever proves the more efficient, may be used.

Mapping and Program Setting

In setting up our maintenance program, the village map was taken and divided into sections, each section being given a number. In connection with the map, a section book, card index and a daily log book was also established. The section-book is made up of all the sewer sections, showing the sewer lines flush manholes, distances between manholes, etc. Each page (map) covers a separate section (see cut) and the crew operating makes constant use of detail maps in the field. The card index is set up



Our Maintenance Truck and Equipment
A 1½-ton unit, which seems a little light. A 2½-ton unit we believe preferable.



Some of the Equipment

Hose and guards in left foreground; a pair of cable winches, against one which leans cable braces with pulleys inserted in manholes to guide cables. In center, a spool of light threading cable and a set of effective metal scouring brushes (8 to 18 in) supplied by the Turbine Company of Milwaukee. Rear center, on chest containing cutting tools and sleds (6 to 20 in.) for Turbine Cutting heads, is a drag and Turbine Cutter complete for 8 inch jobs.

for each section and any conditions found worth remembering for the future is recorded on such cards. The log book maintained to show a complete record of all work done in connection with maintenance and cleaning, carries daily reports showing the number and location of the work section, the type of equipment found needed, number of feet of sewer cleaned, remarks on conditions, number of laborers employed and cost of the job for the day. A specimen page from the current log-book is here reproduced to better picture the type of entries made.

The plan of maintenance is so arranged that at least 78 miles of sewer will be checked once every three years or 26 miles yearly. The actual working time is 5 days per week during the spring and summer months only, involving in all about 150 days per year of maintenance work. The program is planned and timed to run from March 15 to July 1st, the work being resumed in September and terminated on November 15th. The reason for such a schedule is that it eliminates this type of work in the hot weather and also in the cold winter season, the two most disagreeable times to do this work in an efficient manner at least cost.

In the program the business area is done during the month of June, work commencing at 4 A. M. and stopping at noon. At this time of the day there is the minimum of traffic of any kind to hinder the work, therefore all work that is interfered with by traffic can be completed by the time traffic does start to move The three man operating crew consists of a leader, who must be a reliable, industrious individual, and two day laborers. A sewer inspector (or the superintendent) orders sections of work to be done, and likewise supervises the work and sees that adequate records are kept.

In connection with organization, consideration must be given to equipment mentioned and a transport for such. The truck does not have to be an unsightly thing. We use a 1½-ton black panel job, but find that a 2½-ton unit is preferable, as more space is available for the equipment, which consists of 1000 feet of hose, manhole and hose guards, Flexible rods and cutting tools, water powered Turbine, cutter, shovels, picks, lantern, flags, tools and emergency first aid.

The operation of the maintenance crew is to put through the sewers a tool that will either indicate a clean sewer, or remove stoppage, or determine the necessity for a more detailed job such as "turbining." In their travels they repair masonry in manholes, pack loose manhole lids that disturb residents because of banging under traffic.

In stopping rattling manhole lids many things were used which were unsightly on the streets. A gum was then used and served the purpose for a time. The most satisfactory thing to date has been a tape packing called "Tapax." It is laid around the full circumference of the manhole lid seat, after thoroughly scraping and brushing it clean.

In the larger sewers (15 inch and above) we find that the large wire brushes, that are part of our "Turbine" line of equipment, can be used more efficiently for cleaning and indicating trouble than can the Flexible steel sewer rods.

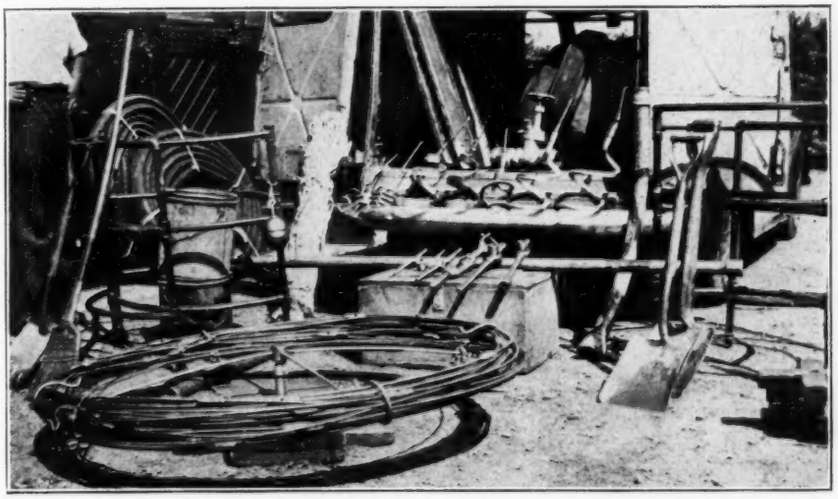
The mere looking down at the flowing sewage, after flushing, does not indicate a clean free-flowing sewer. This much the experience related previously herein has taught us.

Flushing

The basic requirements for effective flushing of sewers are splendidly presnted by J. D. Watson in WATER WORKS AND SEWERAGE for August, 1937. [The same article being reprinted in the Reference and Data Section for 1939.—ED.]

Sewers today are flushed both manually and automatically. The former method is done by using a hose or drawing from pond into the end manhole of a section of sewer line, known as a flush manhole. Also there is the automatic flush equipment frequently installed at the end of a line. The equipment includes a siphon arrangement built into the manhole and discharging into the sewer. The flush tank is continuously refilled by a constant regulated flow of water into it, the rate being controlled by a special faucet. In operation, the flush tank is filled to a certain depth by the water from the faucet. When the head of water is sufficient to cause the siphon to start operation, the siphon empties the tank rapidly and thus flushes the sewer. The idea in all cases of flushing, be it drawn from a pond, by hose, or automatic flush tank, is to cause the flowing off of sewage solids depositing in a flat grade or "lazy" sewer. The hose flushing is the most practical and effective method, as it can be applied anywhere along the line.

The automatic flush, which is still being used, has to be main-



Rear of Truck—More Equipment

Flexible sewer rods connected and coiled on revolving wheel stand. Rear of truck, replacement rods and various types and sizes of augers and screw heads (4 to 10 in.) for Flexible rod work; stop valve for controlling pressure from hydrants used in flushing and Turbine operations; Flexible rod man-hole guides, wrenches and ratchets; man-hole guards flag-stands, etc.

tained. The strainer and orifice through which the water flows to the tank has to be kept clear. Varying pressures in the water main has a tendency to loosen iron deposits which choke the strainer or orifice; also water that has been treated with lime and chlorine causes clogging and trouble with such equipment. There is also the cross connection hazard with this type of equipment which is now being eliminated as much as possible.

As mentioned before, a flow of water will not indicate a clean sewer. Unless properly applied water flow alone will not clean a sewer from a practical man's point of view, other than to flush through material that has been scraped and cut loose or those deposits that are rather easily moved. To clean a sewer effectively involves the removal of films that are building up to a thickness. To accomplish this, the positive scouring type of jetting nozzles must be run through the entire sewer. The flow from a fire plug may seem terrific on entering the line, but very soon levels out to nothing more than a fast flowing stream. As to how much it removes from the walls of the pipes is speculative.

Roots and Service Connections

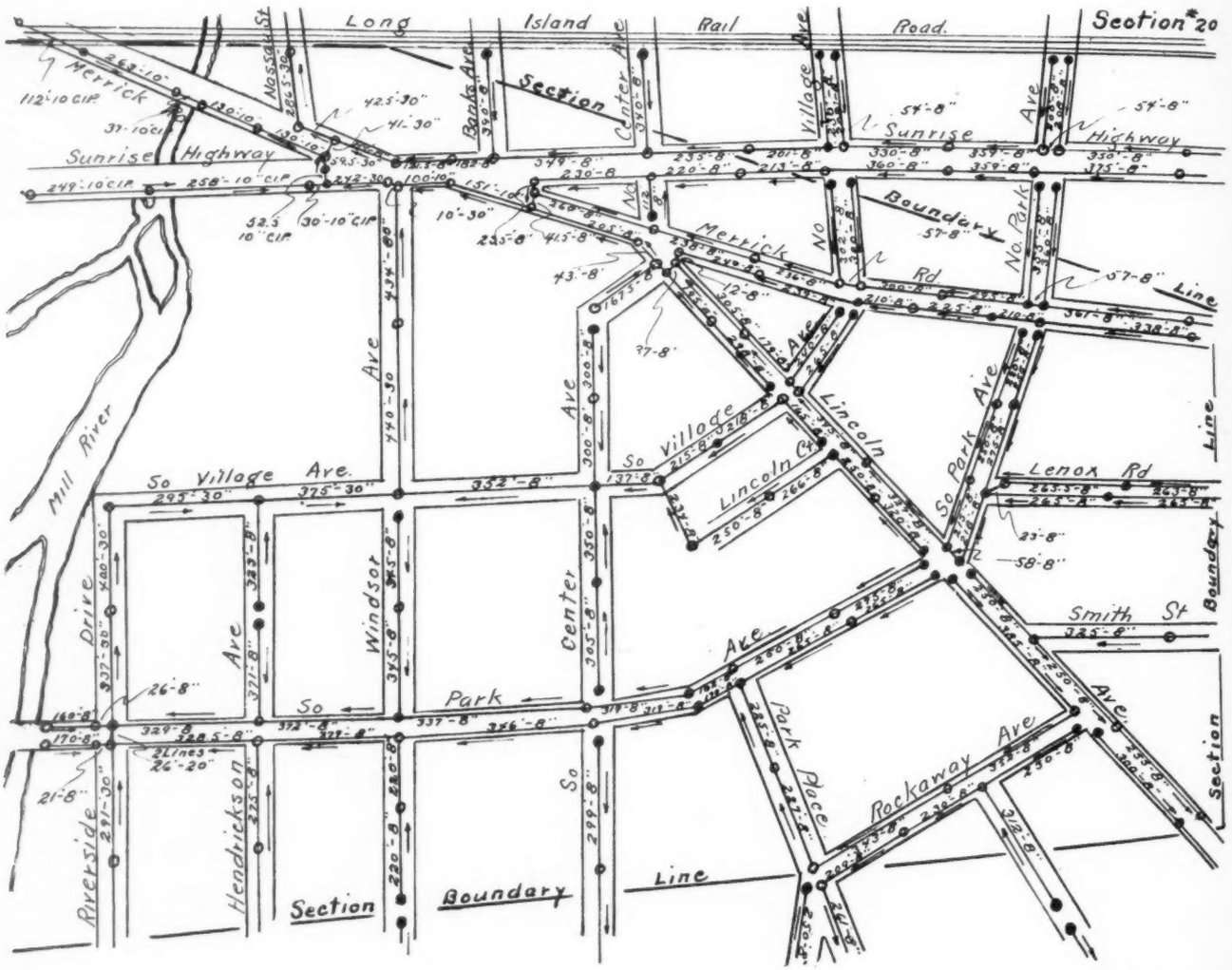
Roots are the big problem in sewer maintenance. We know where they come from—but how to control them? We can to some extent cut down the trouble in the following:

1. Stricter inspection of new lines being laid.
2. Material used for joints. This is no better than workmanship of labor performing the job.
3. Ordinance directed to elimination of the most prolific root growing trees such as poplars, swamp maples, weeping willows, etc.

It has been interesting to hear some of the reports as to how roots will be attracted to sewage, passing up water directly under them and reaching out for a crevice or bad joint in a sewer line. There are many contributing factors—the temperature of sewage, and its content of plant food being the more important.

Service connections into sewers should be inspected as to grade and workmanship of a joint. A poor grade and joint means future trouble for all concerned,—user and Sewer Department. It is so easy to take drain-layer's and plumbers' word for the work done, but once inspected and passed the installation becomes the responsibility of the department passing it. You may argue the point later and think that you have won out, but the taxpayer finally has his day, as we have witnessed so much of late.

The responsibility for maintenance of sewer connections results in a dispute many times. I contend and carry out the policy that where service charges are not made, a sewer lateral should be the sole headache of the one using it. The sewage and waste that is run out to the sewer comes from that property. Any trees in the vicinity are for his comfort, and for a department to take over responsibility from the curb to the main leaves us with the question, Where is the end? Most Sewer Departments have a limited personnel, and to be called out on each house stoppage occurring certainly makes a condition of despair many a time, because of the inability to catch up or demand more labor, which cannot



Detail Map—Section No. 20—Business District

Taken from our Section Map Book covering the 24 sections of the Rockville Center System—Practically indispensable in effective and economical maintenance work, recording, trouble finding, etc.

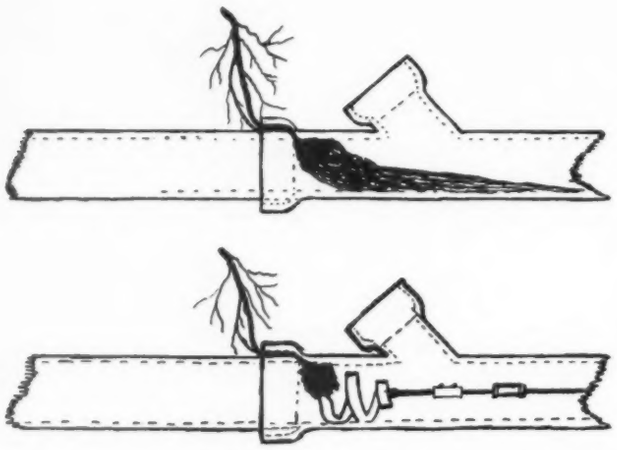
MAINTENANCE RECORD

RECORD OF ALL WORK DONE PERTAINING TO MAINTENANCE OF SEWERS

DATE	LOCATION OF WORK	SECTION	TYPE OF WORK DONE: FLEX. RODS	TURBINE CUTTER	FLUSHED	TOTAL FEET CLEANED	MISCELLANEOUS	REMARKS	NO. OF MEN	NO. OF HRS.	COST
4/4/39	So. Park Ave. bet. Lincoln Ave and Center Ave. S/S	20	X		X	489'		Found bad root condition	3	8	
4/5/39	S/S Lakeview west of Greenway St.	1	X		X	180'	On Complaint	Found break in line about 3' from 1st. d.s.m.h. that filtered water & sand into sewer	3	8	
4/11/39	S/S Park Ave bet. Center Ave and Riverside Drive	20	X		X	1053'		Bad root condition.	3	8	
4/11/39	N/S Park Ave. bet. Riverside Dr. and Center Ave.	20	X		X	1038'		Root condition - not bad	3	8	
4/12/39	N/S Park Ave. bet. Center Ave. and Lincoln Ave.	20	X		X	731'		Bad root condition	3	8	
4/12/39	S/S So. Village Ave. bet. Lincoln and Merrick Road	20	X		X	265'	On Complaint	Found roots in this line, no trees within 150' of stoppage	3	8	
4/13/39	N/S Park Ave. bet Center Ave. and Lincoln	20	X		X	275'		Bad root condition	3	8	
4/14/39	Center Ave. bet. Park Ave and Shellbank	20	X		X	869'		Bad root condition - broke several rods	3	8	
4/14/39	Windsor Ave. bet. Park Ave & flush manhole So. of Park	20	X		X	443'		Some roots - not bad enough to give trouble	3	8	
4/17/39	Windsor Ave. So. from flush manhole to Shellbank Place	19	X		X	443'		Light roots	3	8	
4/17/39	S/S Lakeview Ave West about 350' from Hempstead Ave	9	X		X	320'	Demonstration	New Sewer Cleaning tools used	3	8	
4/18/39	Hendrickson Ave. from Park Ave so. to Shellbank Place	20	X		X	930'		Bad root condition	3	8	
4/18/39	Hendrickson Ave from F.M.H. No. to So. Village Ave	20	X		X	323'		Very bad root condition	3	8	
4/19/39	Hendrickson Ave from F.M.H. So. to Park Ave.	20	X		X	371'		Very heavy roots	3	8	
4/19/39	Windsor Ave. from So. Village to a point half way to Park	20	X		X	345'		Very heavy roots	3	8	
4/20/39	Windsor Ave from a point half way bet. Village, Park to Park	20	X		X	345'		Root condition - not bad	3	8	
4/20/39	Center Ave. from Park Ave to Village Ave.	20	X		X	655'		Bad root condition	3	8	
4/21/39	Lincoln Ave. W/S from Lincoln Court to So. Village Ave	20	X		X	165'		Light roots	3	8	
4/21/39	So. Village Ave. from Lincoln Ave. down to Windsor	20	X		X	922'		Heavy root growth bet Lincoln Ave & Center Ave line partly clogged with sand	3	8	
4/24/39	W/S Lincoln Ave from So. Park to Lincoln Court	20	X		X	470'		Light roots-line very sluggish	3	8	
4/24/39	Lincoln Ct. from Lincoln Ave to Pa.R.W. to So. Village Ave	20	X		X	750'		Light roots-Lincoln Ct.-Sewer opposite Lincoln Inn, filled with grease	3	8	
4/25/39	Center Ave. from So. Village to Merrick Road	20	X		X	767'		Light roots near Merrick Road	3	8	
4/25/39	Lincoln Ave. W/S from Merrick Rd. to So. Village Ave.	20	X		X	558'		Heavy root growth near Petitte Bros.	3	8	

COST PER OPERATING DAY - PLANNING - ADMINISTRATION SUPERVISION AND LABOR @ 25.00

Page from Maintenance and Repair Log Book, Revealing Records Kept



Type of Top Root and Knob Which Calls for a Positive Cutter Here the water pressure driven cutter does the job.—See Text.

always be justified. The use of castiron house connections will eliminate much grief for all concerned.

The policy as to sewer connections lays with a governing body of a community, and it is the duty of an officer of a department to bring forcibly, and with clarity, any constructive measures that he recommends. If this is done, he has done his duty to himself and the taxpayer. It is his duty then to carry on to the best of his ability.

One of Our Pets
A prize root which tore away, leaving a five-finger knob on the top inside of pipe —see sketch—which was still a stoppage producer.

Pump Stations

The pump station is the central point to which all gravity lines feed, and it puts us in mind of a large city into which everything pours and straggles, and with positive energy must clear itself to survive. And so in our pump stations, consideration must be given to what comes in and to what extent we must go to dispose of it. The very mention of a pump station brings to us the fact that there is equipment to be considered. Screens, be they bars or baskets or mechanical grinders, have to be kept clean and the mechanism has to be checked regularly for lubrication, wear and tear. Pump and motors should be inspected regularly as to alignment, lubrication—changing old oil and grease at least once a year. Check pumps for clogging, also condition of packing. Pumps should be taken down at least once every five years, if they have run that long without trouble. In that way parts may be replaced at your pleasure and not at some inconvenient time, as an emergency. The conditions under which a pump works more or less determines the time for inspections.

Chlorinating equipment should be inspected for leaking joints; exposed parts should be covered with vaseline; strainers and other parts that clog with salts should be inspected as often as necessary. Under ordinary conditions once every three months is sufficient. Chlorine causes considerable trouble to electrical equipment and the two should never meet. Newly designed stations have a complete separation of the chlorine room from other parts of the building.

The well into which all the sewage flows should be kept clean for at this point sludge and grit settle out and putrifaction and odors set up which become a nuisance to surrounding properties. Daily flushing of a well is the most efficient way of keeping it clean. Any solids or grit which have settled can easily be flushed away with an inch and a half hose and nozzle. While considering the adjacent property owners, it is well to consider the beautification of the grounds and maintenance of the inside and outside of the building. The care of pump stations, if there are enough of them, warrants a utility man whose job it is to keep them in condition.

Costs

The cost of this type of maintenance shows an excellent economy in the form of a satisfied public, and also in dollars and cents. The equipment needed for effective maintenance totals some $2,700, and we plan on replacement every three years. Depreciation and interest runs the equipment cost to about $900 per year for our system. To this must be added $25 per day for 150 days per year to cover planning, administration, supervision, labor—say $3,750 per year.

Based on a coverage of 26 miles (137,280 feet) the cost per foot of sewers cleaned and maintained is—

$$\frac{(150 \text{ days} \times \$25) + \$900}{137.280 \text{ ft.}} = \$0.34 \text{ per foot.}$$

To cover liability, other insurance, and miscellaneous items such as gasoline, water used, etc. The cost may run to 4 cents per foot maximum.

Summing Up

The old method of sewer maintenance, which usually amounted to keeping the fingers crossed until the next call for help is made—then digging up the streets, making repairs, refilling and repaving, resulting in disgruntled taxpayers—is very expensive as against an orderly economic sewer maintenance program. At least such has been our experience in Rockville Center.

For another splendid article on "Sewer Maintenance" see that by J. H. LeChard, Chief Engineer, Atlantic City Sewerage Co., in the Reference & Data Issue of 1939 (May) page 190.—Ed.

TURBINE SEWER MACHINE CO.

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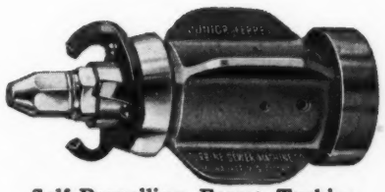
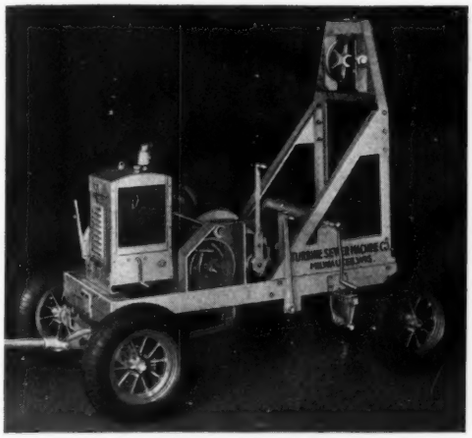
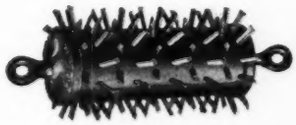


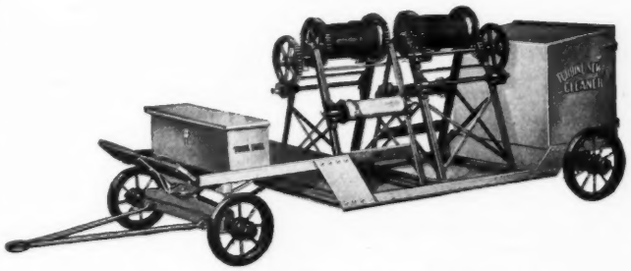
Self-Propelling Ferret Turbine



Power Sewer Cleaner

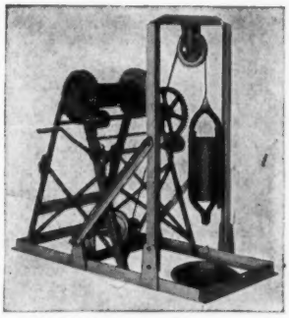


Turco Hercules Sewer Brushes

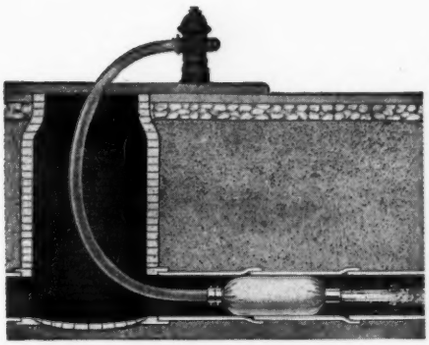


Complete Turbine Type Sewer Cleaner

Sewer Rods

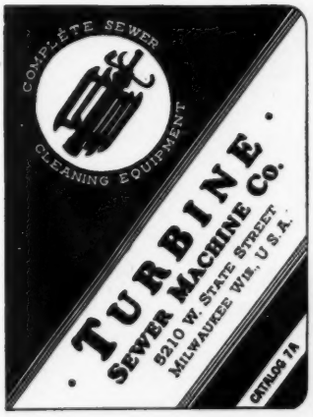


Senior Type A, Windlass with Boom



Turco Sewer Flushing Bags

Ree-Peters Root Harpoon



Write for this Catalog

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MIDDLETOWN, OHIO

FABRICATING PLANTS THROUGHOUT THE UNITED STATES AND CANADA

ASBESTOS BONDED ARMCO SEWER PIPE

MULTI PLATE PIPE AND ARCHES

PERFORATED METAL PIPE • FLUMES

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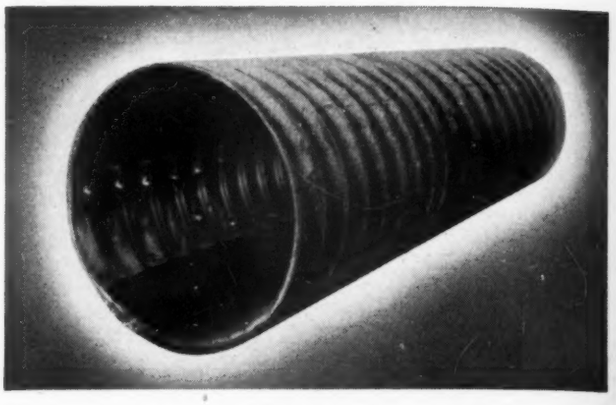
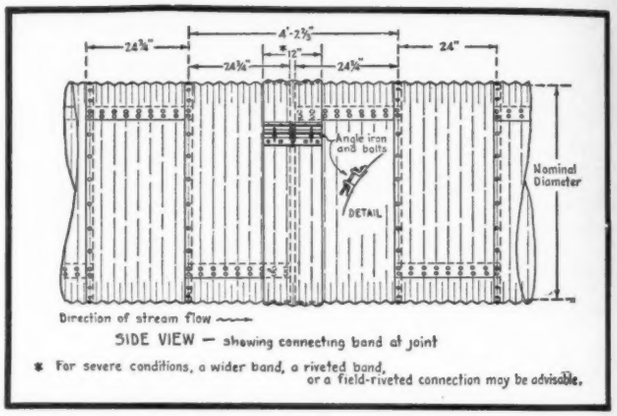
DRAINAGE GATES • STANDARD FULL-ROUND AND PART-CIRCLE CULVERTS



Asbestos Bonded Armco Sewer Pipe.



Fabrication details of Armco Sewer Pipe.

ARMCO SEWER PIPE

A full-round corrugated pipe made of galvanized ARMCO Ingot Iron. Paved in the bottom and fully coated with a special bituminous material which is mechanically bonded to the pipe by means of asbestos fibres embedded in the galvanized coating.

Armco Sewer Pipe is quickly available in diameters from 8 to 96 inches, including connecting bands and standard or special fittings. Individual lengths up to 20 feet. Write for 48-page illustrated book on sewers containing useful design information.

RECOMMENDED GAGES FOR ASBESTOS BONDED ARMCO SEWER PIPE

	DEPTH OF COVER (H), FEET								
Diam. D Inches	1 — 2	2¼ — 7	7½ — 10	11 — 15	16 — 20	21 — 25	26 — 30	31 — 35	36 — 40
12	16	16	16	16	16	16	16	16	16
15	16	16	16	16	16	16	16	16	16
18	16	16	16	16	16	16	16	16	14
21	16	16	16	16	16	16	16	14	14
24	16	16	16	16	14	14	14	14	14
30	14	14	14	14	14	14	12	12	12
36	14	14	14	14	14	12	12	10	10
42	14	14	14	12	12	10	10	8	8 *
48	14	14	14	12	12	10	8	8	8
54	12	14	12	10	10	8	8	8	8
60	12	12	* 12	10	8	8	8	8	8
66	12	12	12	8	8	8	8	8	8
72	10	12	10	8	8	8	8	8	8
84	8	10	8	8	8	8	8	8	8

Note: The gages shown are based on a maximum deflection of 5% for the following loadings:
1—Live Load = H 20 + 50% impact = 24,000 lbs. concentrated surface load.
2—Dead Load = Embankment (ordinarily heavier than ditch loading.)

*** For pipe below heavy black lines consult an Armco engineer for installation instructions.**

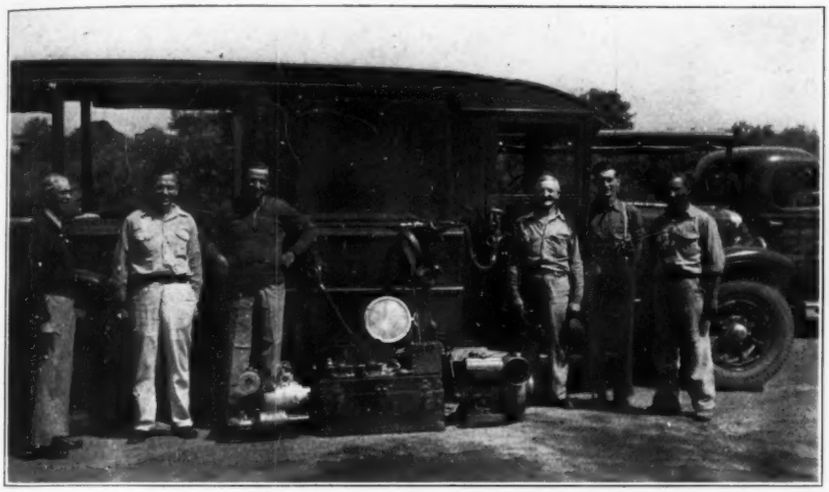
SEWER SERVICE AND MAINTENANCE

Radio Equipped Service and Maintenance Truck Proves Its Value

By EDWARD P. DECHER

Ass't. Secretary and Purchasing Agent
The Joint Meeting, Newark, N. J.

First, it should be explained that the Joint Meeting is a Sewer Commission and is comprised of the following eleven municipalities: City of East Orange, Town of Irvington, Township of Maplewood, Township of Milburn, City of Newark, Village of South Orange, and the Town of West Orange, all being in the County of Essex. In the County of Union are the Township of Union, Township of Hillside, Boro of Roselle Park, City of Summit.



No. 1.—Radio Equipped Maintenance and Service Truck and Equipment (Henry Decher, Ass't Foreman (left) and Crew)

The Joint Trunk Sewer

The Joint Trunk Sewer is constructed within the boundaries of the aforementioned municipalities. The original sewer was built in the year 1900 and is approximately 23 miles in length. A Supplementary Joint Trunk Sewer was completed in the year 1930 to give a total of 54 miles of main trunk sewer in all.

The Joint Trunk Sewer at the present time is serving an estimated population of about 305,000. The Sewage Treatment Plant is located in the City of Elizabeth, the final effluent discharging into Arthur Kill. One can readily see that should our men and equipment be working in the Town of West Orange and an emergency should arise in the Boro of Roselle Park or at our Treatment Plant (the plant being about 12 miles from the Town of West Orange) a difficult task would be encountered in contacting the men or securing needed equipment.

Our Truck Now Radio Equipped

Because of the distances involved it was deemed advisable by the Hon. Peter A. Smith, Chairman of the Joint Meeting, to equip one truck, at least, with a short-wave receiving set for the purpose of reaching our maintenance and service crew in the shortest possible time in case of an emergency or a complaint received which justified attention with least delay.

The radio set was purchased at a cost of $170.00 and installed on our three ton International truck.

The following is a list of the equipment carried on our two motor trucks:

1 Hydrogen Sulfide Detector.
1 Wolf Safety Lamp.
1 Combination Velocity Blower Hose Mask with Safety Harnesses.
1 Carbon Monoxide Detector.
2 Canister Type Gas Masks.
Carbon Monoxide Detector Ampoules.
2 Pairs Chippers Goggles.
1 2½" Portable Air Blower.
1 Combustible Gas Indicator.
1 Industrial First Air Kit.
4 Extra Safety Belts with ropes attached.
Salt tablets for use in the prevention of heat sickness.
1 1500 Watt Portable Electric Generator and Floodlights.

The Joint Meeting has six employees on General Sewer Maintenance (see photo No. 1) and all of these men have taken a course in First Aid which course was given by the Newark Safety Council. Besides being capable of administering first aid, all of the men are trained in the proper use and operation of the many safety devices carried on our equipment at all times.

Our ment are especially instructed in the use of the hose and canister type masks. The Joint Meeting will not permit any of its men to enter a sewer or any sub-surface structure with a *canister* type mask which is of no value in oxygen deficient atmospheres.

We have heard of water service trucks that have been radio equipped. However, at the present time, I know of no other sewer truck equipped the same as the one owned and operated by the Joint Meeting, and I believe that it is the first sewer truck in the United States equipped with radio.

In photograph No. 1 is seen the two maintenance trucks (the larger being the radio equipped unit), some of the equipment

No. 2.—Some of the Equipment (See text for description and uses)

listed above (see Photo No. 2), and the General Maintenance Crew.

Equipment

Portable Generator

On the left is our indispensable Homelite Portable Generator good for 110 volts D.C. and 1250 Watts. In center, the floodlight. Both are products of the Homelite Corporation of Port Chester, N. Y.

With this generator we have several electrical tools and flood lights. These electrical tools have been found to be very satisfactory. We have never at any time found ourselves without proper lighting when emergency work is performed at night. We have approximately 200 feet of special extension cord, should the necessity ever require special lighting in our large sewers when repairs are made. A good portion of our sewers are in outlying territory where electric current to be supplied from a nearby house is impossible.

It may be interesting to note that the Joint Meeting has two cast iron pipe sewers, one being 36 inches in diameter and the other 54 inches, which run parallel and lie on the top of the ground in the Township of Union and each being approximately 1500 feet in length without any manholes. It has been recommended by the Chief Engineer—Leslie E. West—that at least four manholes be built on each line and the type recommended are Hat-Flanges, with bolted covers. To install these Hat-Flanges our portable generator will play a very important part, that is for furnishing the current to drill the necessary holes in the present pipe in order to fasten on the Hat Flanges. If it were not for this machine it would require drilling these holes by hand or renting the equipment.

On two occasions power failures were encountered at the Treatment Plant. We were able to supply the necessary light until the current was restored. Our generator has proven a very sound investment, if not an indispensable one.

Blower, Hose Masks and Gas Detectors

The next item in this photograph is the trunk-like case which contains the blower and the hose type gas masks. This piece of equipment is manufactured by the Davis Emergency Equipment Company, Inc. of New York City. On the top of this case are two carbon monoxide detectors, two hydogent sulfide detectors, and one combustible gas indicator. The last two items of equipment are products of the Mine Safety Appliance Co. of Pittsburgh, Pa.

Portable Air Blower

The last item in this photograph is the portable air blower (on the right) manufactured by the B. F. Sturtevant Company of Boston.

This piece of equipment has proven very satisfactory and is used in ventilating sewers before men are allowed to enter. It has also been used at our Treatment Blant in drying out the tunnels. There also appears on this photograph, hanging from the side of the truck, the headpiece and safety belt of the gas mask. This equipment as shown is carried at all times with the necessary First Aid equipment on this truck. A combustible gas indicator manufactured by the Davis Emergency Equipment Co., together with the duplication of the carbon monoxide and hydrogen sulfide detectors are carried on our other truck, and another set is stationed at our Treatment Plant.

The writer believes that no municipality can afford to be without the necessary safety equipment for the protection of their employees. While the cost of the aforementioned equipment is most reasonable, it is priceless in the event of an emergency.

Flexible Sewer Rods

The Flexible Sewer Rod shown in Photograph No. 3 has proven to be a very satisfactory piece of equipment. This piece of equipment, manufactured by the Flexible Sewer Rod Co. of Los Angeles has many advantages, such as can be seen. One can readily understand that the old method used in removing an obstruction in a sewer that only one man could be placed in a manhole, in a cramped position, at a time, thereby reducing his strength to a minimum when working. With a flexible sewer rod you can notice in the photograph that more than one man can be used and greater

No. 3.—We find the Flexible Rod to Have Many Advantages Looking into the manhole are Henry Decher, Foreman, and (right) Corey W. Sanford, Superintendent of Sewers.

No. 4.—Pollard's Portable Platform Derrick (On the platform, a turbine wench; Superintendent Sanford, Portable Homelite Generator and Flood Light)

No. 5.—Our Chief Engineer, Leslie E. West, Demonstrates the Test for Poisonous and Combustible Gases

pressure exerted, and the safety feature is that the men are on top of the ground at all times during this particular operation. We have found that an obstruction can be moved much faster with this piece of equipment than the methods used heretofore, and that more territory can be covered in a shorter time. There are also many other advantages.

Portable Derrick

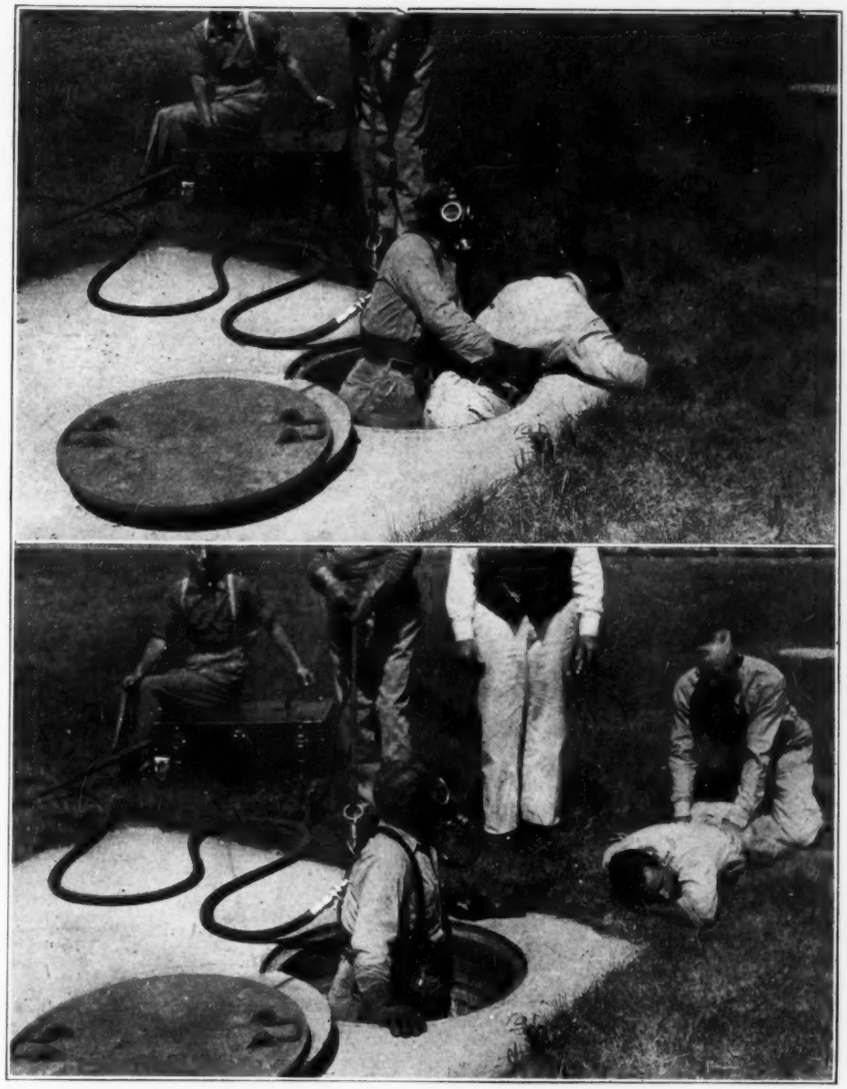
The portable derrick shown in Photograph No. 4, manufactured by The G. J. Pollard Company of Brooklyn, N. Y., is known as the Pollard Portable Derrick. The platform on this derrick is large enough to transport our two Turbine Sewer Cleaning Wenches (Turbine Sewer Machine Co. of Milwaukee) with the drum and cables intact.

These wenches, with the drums and cables, are rather heavy but can be easily placed on the derrick platform without much effort, due to the fact that the platform is only 12 inches above the ground. This platform derrick is equipped with a set of small rubber wheels in the center, and is towed on the rear of our truck from one job to the other.

The derrick has a lifting capacity of 1000 lbs. and can be swung in any position desired. It has been used to lower pipe on some of our repair jobs, and used in raising tilting buckets out of manholes during sewer cleaning operations. It has also been used very successfully in loading heavy manhole heads and pipe on our truck, therefore making loading much safer. This piece of equipment has proved highly useful.

Rescue and First Aid Practice

Photographs No. 6 and No. 7 show our employees giving a demonstration of the proper method of rescuing a man, should he be overcome while working. There may be a possibility that the reader seeing the photograph may criticize the fact that we permitted a man to enter a sewer or chamber without the proper equipment, however, this is not the case with the Joint Meeting. I believe, though, that the fact can be appreciated that it is a hard task to have a man working in a sewer wearing a gas mask continuously, if the conditions under which he is working are absolutely safe. Extensive tests are made before any man is permitted to enter any of our sewers. We have quite a number of meter chambers which are far above the sewer line itself. These must be entered by our employees each week to change the meter charts, and in performing this duty it is not always necessary for a man to be equipped with a mask if conditions are safe, however, one can never tell when an employee may be suddenly attacked by some gas. For this reason our employees must go through a rehearsal such as pictured, so that they do not lose their technique and ability in case of an emergency.



Nos. 6 and 7.—Rescue and Resuscitation Practice Is a Requirement of the Joint Meeting

Compensation Insurance

The Joint Meeting carries compensation insurance, which we believe is very necessary. Regardless of how minor an injury may be, even to a small scratch on the finger, the employee must go to a doctor for the necessary treatment. This is to insure their safety and to minimize claims against the Joint Meeting.

Last year all of the employees of the Joint Meeting were inoculated against typhoid fever. This was paid for by the Joint Meeting as a safeguard to its employees. The Joint Meeting makes every effort to see that its employees are protected from any hazards and makes it a practice to have a safety engineer from the insurance company make regular inspections of the equipment and Treatment Plant every month. And, at the same time the inspection is made a safety meeting is held by our employees, they having an opportunity to discuss problems pertaining to the plant with the safety engineer.

Safety Equipment Demonstrations

In June, 1938 the Commissioners of the Joint Meeting held a special meeting at the Treatment Plant for the purpose of gaining as much knowledge as possible for themselves and the employees on safety measures. The principle speakers at the meeting were Mr. E. M. McCool of the Mine Safety Appliance Co., and Mr. L. W. Brendlen of the Davis Emergency Equipment Co. They gave a very splendid lecture and demonstration on the proper uses of the various safety devices used in connection with sewer work. This meeting was attended by approximately 100 officials connected with the municipal sewer departments in Essex and Union Counties, New Jersey.

Employee Suggestion-Box and Prize Contest

There is installed on the wall in the Treatment Plant a box known as the Suggestion-Box in which suggestions are deposited by our employees. Employees have continuously placed suggestions in this box and, after being given careful consideration, the most practical are tried. A number of the suggestions submitted have been found to be decidedly beneficial. It is a commonly known fact that men in constant contact with equipment are those most able to express its advantages and observe wherein improvements would bring about better results. The Commissioners of the Joint Meeting have discovered that many of these suggestions have resulted in a considerable saving in dollars. For this reason the Commissioners of the Joint Meeting have set up two prizes for a contest which is now in progress, giving each employee an opportunity to express his views as to what in his opinion would better serve the Joint Meeting as operation of the Treatment Plant, maintenance of the sewers, safety of the employees, or any other item pertaining to the works in general.

PROPER SEWER JOINTING*

And Other Effective Construction Procedures to Preclude Infiltration

By WILLIAM A. GOFF
Consulting Engineer, Philadelphia, Pa.

The method of constructing joints in sewer pipes is directly related to the success or failure of the construction of a sewer system.

Those who are conversant with the many factors in the design of a sewer system, sewage treatment works, and allied units of construction, know the importance of restricting infiltration of the pipe lines to a minimum.

The extent of infiltration is not only indicative of the general character of construction of the work performed. Low infiltration leads to economy in the operation of the system and works and reserves for future use the capacity of the pipe lines and works that otherwise would have been utilized through the conveyance of needless volumes of ground water.

The effort put forth today in the treatment of sewage, which in a majority of cases requires initial pumping and in many instances secondary pumping, emphasizes the need of tighter sewers. It is readily discernible that every drop of water that enters the lines and is pumped and treated, involves costs.

There are unquestionably numerous factors directly related to the infiltration of pipe lines, but there can be no question that the most important factor entering into this particular phase of construction is the method of constructing the joints.

In the established practice of awarding contracts to the lowest bidder, there is little or no definite assurance of the qualifications of the men who will do the work. Under prevailing conditions in public contracts a contractor is not selected on his record of satisfactory construction performance, but rather upon the price bid. While a contractor himself may be most willing to perform his contract satisfactorily, it is actually the men who work in the trench who are the keystone of performance.

The Importance of Exacting Specifications.

To afford these men the opportunity of producing satisfactory results, the engineer must of necessity know the conditions under which these men are to work, and provide in his specifications such methods of construction as will enable these men to perform their work in a satisfactory manner. In addition, the contractor must cooperate with all of his facilities in an endeavor to produce the results desired. It is this thought that I have uppermost in my mind when planning and designing a system of sewers, for I fully realize that unless the men who actually do the work are provided with a suitable method of construction, the finished product will not be satisfactory regardless of their efforts.

I have found that where a large portion of the sewer joints are to be under three or four feet head of water, that the dewatering of the trenches by the method of well points, has been the most successful means of providing favorable working conditions for the men making the joints in the trench.

Value of Trench Dewatering by Well Points.

This pre-draining of the construction area prior to the commencement of excavation does three things:

First—It provides the contractor a dry ditch in which to work and also gives the inspector a better chance to inspect the joints.

Second—It reduces by a considerable amount the need for sheeting and shoring. In the majority of cases of pre-draining the sides of the bank will remain standing, even in sand, with only skeleton bracing.

Third—It eliminates all needs for special construction, such as concrete encasement or cast iron sewer.

All of these things affect the cost and incidentally help to create tight joints, all of which is very important.

After affording favorable working conditions for the men in the trench, the next step is to provide a suitable joining material and the method of its construction to obtain the desired objective.

The Most Effective Joint.

Outstanding are the bituminous joints, both hot and cold. Basically they are composed of coal tar or asphalt, mixed with powdered inert materials and either poured into the joint while hot and allowed to cool, or preformed joints inserted in the joint space and pushed in place when the pipes are assembled.

Jointing with hot poured compounds has the advantage of completely filling the annular joint space, more permanent adhesion to the pipe sides, and a degree of resiliency which will permit slight movements of the pipe line.

Preformed joints have made their appearance on the market and have been used with various degrees of success. One preformed joint, consisting of collars of felt impregnated with these asphalt compounds, made in sizes to fit the commercial pipe sizes, is slipped over the spigot end of the pipe and forced along with the pipe by means of a mechanical jack, into the bell of the receiving pipe; the natural resiliency of the preformed joint distorting to fit the shape of the bell and spigot. Another preformed joint which has been used with good results is made by the use of metal dies clamped in the bell and around the spigot of pipes and poured with hot compound prior to lowering the pipe into the trench. At the time of assembly the two preformed collars are painted with a solvent and pushed together the solvent causing the collars to fuse and thus form the joint.

Jointing Experience

The type of joint which I have been using for the past seven years is the result of numerous experiments and actual field tests, and consists of the following:

Oakum packing of approximately 1-inch in depth.
A hot bituminous joint of approximately 1½ inch in depth, and an outside cement mortar fillet wrapped in a muslin cloth tied tightly in place.

Such a joint sounds complicated, but my experience shows that after the ditch-men become experienced, the joint can be made rapidly and consistently perfect. Perhaps this joint does add a few cents to the per foot cost of the sewer, but what of that. The owner is buying a sewerage system and he wants a good one. It is distinctly worth while to avoid infiltration and all will agree that there is only one time to get tight construction and that is when the sewer is built. Any small initial increased cost of construction is soon compensated by the economies possible where the infiltration is negligible.

Laying Specifications.

In the construction of the joint I specify, the pipe be laid by two men, one holding the spigot end of the pipe in a "U" shaped sling consisting of perhaps two strands of jute at the end of the pipe while the other man pushes the pipe home from the bell end. After the pipe is home the front man wraps the oakum over the pipe and pushes it in place with a caulking iron, so as to provide proper space for the bitumen, while the back man tests the pipe for elevation with a grade rod from the line above and checks for line by a plumb bob from the same line, and makes such adjustments as necessary. He then moves forward, checks the subgrade for elevation and excavates bell and a length four inches longer than the circumference of the last pipe laid and determines if it is free of water. The next pipe is then handed down into the ditch and laid as before. The top man, before handing the pipe down, ties on the bell end of each pipe a piece of muslin with a width of six inches greater than that of the bell and a length four inches longer than the circumference of the bell. This cloth has been torn to provide tie strings at each of the four corners. Another man follows behind and places around each bell a runner fastened

*From *Proceedings of the Twelfth Annual Conference of the Maryland-Delaware Water and Sewerage Ass'n.*

with a clamp at the top. Into this runner mouth he pours the hot joint compound, being careful to keep runner filled at the top and see that there is no leak at bottom or sides.

When cold, the runner is removed and the muslin band pulled out under the joint and completely filled with a cement-sand mortar (1:2) to form a 45° fillet around the outside of the bituminous joint. The mortar is pushed under the pipe to fill the band and the cloth band is then pulled tightly up and tied with the two remaining strings across the top of the pipe. The joint man then encircles the pipe with his hands and makes sure that the muslin band is completely packed with mortar, *especially at the bottom,* and that the band is tight. He then draws his hands upward, pressing the joint and dresses the top. Of course the mortar must be fairly stiff. It is not as complicated as it sounds, and contractors who have worked under me are generally enthusiastic after their men get the swing. It makes a *good* joint. The men know it. The inspector can check it. The contractor can see it and knows that future infiltration trouble is ended.

Features of This Joint.

The joint itself is correct. The oakum prevents the bitumen from getting into the pipe. The runner forms a tight channel for the bitumen which fills the annular space, adheres to the pipe surface and forms a tight joint. The bitumen can be readily inspected when the runner is removed. The cement collar reinforces the bitumen and provides maximum reinforcement where there is the greatest chance of a slip in the bitumen joint. That is as always, at the bottom. If by accident there should be a poorly poured bitumen joint the tightly packed cement mortar fillet will be forced into the hole and the rag will hold it there while the mortar hardens. The mortar fillets tends to give rigidity to the joint. The rag prevents backfill on a freshly made joint from disturbing the joint.

Results.

Results in the use of this joint have proven remarkably successful. Nowhere have contractors failed to meet the severe infiltration limitations I have set up in my specifications where I have used this joint.

In Harrington, Delaware, for instance, we constructed 8.08 miles of sewers, of which about fifty per cent was wet trench with an infiltration only 6.6% of the allowable.

In Berlin, Maryland, we constructed 7.97 miles of sewer of which 30% was wet trench with an infiltration only 7% of the allowable.

Other Records	Miles	Percent of allowable
Spring City, Pa.	9.59	27
Florence, N. J.	12.14	20
Conshohocken, Pa.	25.08	3
Georgetown, Del.	8.36	21
Clarks Summit, Pa.	18.99	68

Think of it, even in the last case we have a 19 mile system with a total infiltration of only 3,790 gallons a day, or less than three gallons per minute. Then consider that a ¼-inch hole under a two foot head of water will give a flow over one-half gallon per minute.

The infiltration limits I specify are as follows:

Size of T. C. Pipe-inches	Gallons-per mile in 24 Hours
5— 6	4,000
8	5,000
10	6,300
12	7,500
15	9,500
18—36	15,000

In the above mentioned list of recent jobs well points were used on Harrington, Delaware; Berlin, Maryland; Florence, New Jersey, and Georgetown, Delaware. In all of these instances quicksand was met and in no case did we use any special construction method.

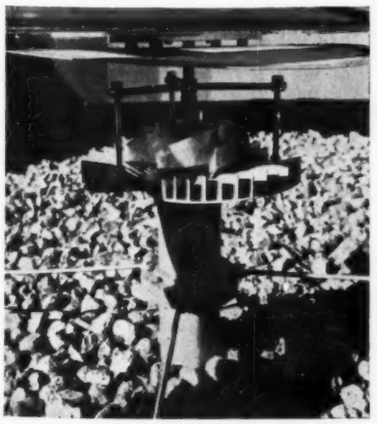
Backfilling.

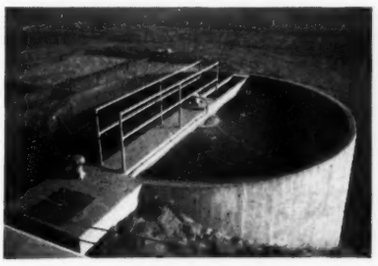
In backfilling the trench care must be taken to use only fine soft earth around the pipe in order to minimize the possibility of cracking the pipe. This initial backfill should be placed equally on both sides of the sewer to prevent dislodging and be carried at least one foot above the top of the pipe and carefully tamped to insure equal solid side foundation around the sewer pipe.

LAKESIDE ENGINEERING CORP.

222 W. ADAMS STREET — **CHICAGO, ILLINOIS**

AERO-FILTER is the trade name of a trickling filter designed to bring about the condition required by the Halvorson-Smith Process. Obviously special equipment for distribution had to be developed. The Lakeside Engineering Corporation held to the ideal of continuous and uniform application to all portions of the filter surface in the development of its disc and rotary distributors. These disperse the sewage in a rain-like spray over each square foot of filter surface practically every second of the day and night. As a consequence no portion of the bed can receive more than its share of the load. The flora on the filtering media are fed uniformly and continuously.





MOTOR-DRIVEN DISC DISTRIBUTORS

Disc distributors have been developed for use in Aero-Filter ranging from 8' to 34' in diameter. The discs are divided into three equal segments. Each segment is equipped with vanes which divide the flow of sewage and shunt it to various areas of the filter bed.

The discs travel at speeds ranging between 260 to 328 r.p.m. However, for any given size of filter the peripheral velocity of the disc is constant. Originally the sewage flowed upon the rotating disc at right angles to the direction of the disc rotation. During the Fall of 1939 a vaned diffuser cone was perfected which greatly reduces the H.P. since the sewage is now passed to the disc in the direction of the disc rotation.

MULTIPLE ARM ROTARY DISTRIBUTOR

In developing our multiple arm rotary distributor, the mechanical arrangements to achieve ideal distribution were made the subject of intensive study. The objectives were:

(1) Application of the sewage in a rain-like form momentarily on a maximum of the filter surface.

(2) Relatively high speeds of rotation to effect practically 100% momentary bed coverage.

(3) Flexibility of adjustment in the field for local conditions to insure application on the entire filter surface for each revolution of the distributor.

(4) Control of maximum distributor speed.

(5) A nozzle design to give a minimum of clogging trouble, and one which can be readily cleaned without disturbing the orifice.

(6) Prevention of mercury blowing when excessive heads may be encountered either from pumping direct into the distributor or as a result of nozzle clogging in plants having excessive heads between the primary and filter. Both inner and outer columns are equipped with large relief openings at the maximum desirable operating head, in such installations.

SERVICISED PRODUCTS CORP.

6051 WEST 65th STREET — CHICAGO

ASPHALTIC SEWER JOINTING MATERIALS

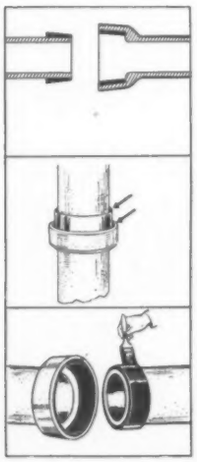
● TWO-IN-ONE DIE-CAST SEWER JOINT ● SEWER PIPE BELT ● SERVITITE ● TUFFLEX ● Q.D. PRIMER ● HOT POURING COMPOUND

TWO-IN-ONE DIE-CAST SEWER JOINT

● Water-tight and root-free joints are assured by the Two-In-One Die-Cast Method. All the work is performed above the ground. Under the Servicised System, the even surfaces of the two cast joints come into close contact and effect a tight joint, making an ideal condition which counteracts root growths, solves the question of centering, is ideal for wet trenches and meets the utmost demands. Under the System it is only necessary to have one die. One pipe is set up on the other and both sections of the complete joint are poured at the same time. All the work is done above the ground, and no stooping over is necessary to pour a joint around the base, as this is done at a uniform level.

● Two-In-One Die is a single die, is furnished and so prepared that the taper of the die takes care of both sealing bands. The die is placed on the bell end of the pipe which is placed up-right and the spigot end of the second pipe rests in the die.

● With the Two-In-One Die-Cast Method of joining pipes, the pipe is always prepared ahead of placing into the trench. The pipe can thus be prepared during any part of the year and in advance of the actual laying, if desired. The Two-In-One Die Method of casting joints costs less than any other method as there is less handling of pipe, less bending over, practically all of the work being done at waist level.



● The Hot Pouring Compound is poured in such a manner as to leave an asphalt band in the bell end of one pipe and a similar band on the spigot end of the other. Before using the die is prepared with a coat of anti-stick preparation so as to avoid any of the asphalt adherring to the die. The upper pipe is then removed and becomes a receptacle for the next set of pipes, the die being removed, cleaned and again lubricated with anti-stick preparation. The spigot now bares an asphalt band and on the bell a similar band which are consistent to each other. Before installing each band is coated with two-in-one solvent which forms the bond assuring an absolute watertight connection.

SERVICISED PREMOULDED SEWER PIPE BELT

The perfect job to be desired in a sewer joint is one which is long-lived, water-tight, flexible, root-proof, and resistent to acids. All these qualifications are met by Servicised Pre-Moulded Sewer Pipe Belt. This belt also provides the important factors; Ease of Installation, Ease of Inspection and Saving of Labor.

THE PRODUCT, NEAT, MODERN, CLEAN

Servicised Pre-Moulded Sewer Pipe Belt, moulded while hot, in the course of manufacture, is belt-shaped and in cross-section is wedge-shaped, conforming to the shape of the bell and giving a wedging action when driven in. The ends of each section of belt are beveled so that when installed tightly there will be no crevice where the ends meet. The belt is calked in to tightly fill the annular space between bell and spigot of sewer pipes. Belts are made for all sizes of pipe according to A.S.T.M. dimensions and special belts are made to order where sewer pipe is not in conformance with A.S.T.M. standards.

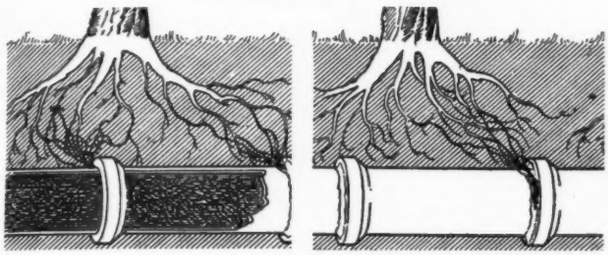
The special composition and properties of Pre-Moulded Belt go together to form a superior product. It is a uniform mixture of selected fibrous asbestos and refined bitumens of special character, such as only Servicised can make due to very wide experience in the fabrication of asphalt specialties.

SERVITITE—COLD PLASTIC COMPOUND

The problem of root-clogged sewer pipes is eliminated by the use of Servitite. Servitite, used cold, does not shrink on hardening. Servitite sets under water. Servitite comes in units of 140 pounds, of which 100 lbs. is in powder form and 40 lbs. in liquid form.

Servitite is manufactured to provide an economical material always on hand for quick use on any sewer jointing job. Servitite is highly adhesive to clay or concrete pipe and hardens shortly after being installed. Servitite is flexible and acid-proof and more than anything—ROOT-PROOF—having incorporated in its composition an ingredient poisonous to vegetation. The special feature of Servitite is its being furnished in two units for mixing on the job as desired Measuring containers are furnished with each order so that the contractor can prepare the desired amount of material to complete the job.

ROOT GROWTH



Inferior Material

No Root Growth with Servitite

SERVICISED RUBBER CAULKING SPONGE

A highly porous soft rubber saturated with Bituminous material which can be compressed 75% of its thickness and fully recover.

Particularly adapted to all places where caulking materials are employed and particularly adapted for this purpose by reason of the fact that after compacting continue to recover its full dimension.

It requires less labor to caulk by reason of this fact and has a tendency to more completely fill the opening in which it is placed, thus preventing any infiltration of water. The hardness of other materials employed causes irregularities of surface and water often passes through these spaces.

The material is germ proof and root proof. This material is well adapted as an inner-lining for cast iron pipe and is also particularly adapted to joint for concrete pipe. It is also material which lends itself very readily and nicely to self-expanding joint purposes.

TUFFLEX

Cold troweling plastic for sewer pipe joints. Like Servitite, Tufflex is also a plastic cold troweling sewer compound. It is highly adhesive and produces an absolutely watertight connection. Tufflex is mixed at the factory and comes to the job ready for instant use without any additional preparation necessary. It is furnished in convenient size airtight drums. When only a portion of the drum is used the airtight cover is replaced to keep Tufflex in perfect condition for future use.

Sewers require repair when broken due to ground movement or trench settlement. Tufflex, being a highly flexible material, will take up this movement and at the same time assure watertightness due to its high degree of adhesion. This eliminates the possibility of foreign matter, root growths and infiltration of surface water. Tufflex also is made with a root deterrent and, being cohesive as well as adhesive, does not allow infiltration which is usually found in non-flexible sewer compounds.

Tufflex has been widely used for many years and is one of the most important pipe joint compounds on the market today. Cold troweling has many advantages over hot pouring or cement grout joints. Preheating time is saved as well as expense of runners and the additional labor saving for installation.

OTHER PRODUCTS

HOT POURING COMPOUND. Servicised Hot Pouring Compounds are specially prepared by experts to meet the extremely adverse underground conditions. They consist of tough flexible petroleum asphalt with a definite percentage of finely ground, insoluble mineral filler. Thus composed, the material remains uniform and raises the softening point of asphalt to increase flexibility in cold weather and prevent erosion and flow in hot weather. The foregoing components can be tested.

Q.D. ASPHALT PRIMER. Q.D. Asphalt Primer is of particular advantage in laying sewer pipe under adverse conditions. Good joints can always be made up by the use of Servicised quick-drying asphalt primer in conjunction with premoulded belt or any of our other jointing compounds, either of the hot pouring or plastic types. This primer is a bituminous material of brushing consistency which, on exposure to atmosphere, sets up into a tough asphaltic seal. The light solvent in Q.D. Primer evaporates after being subjected to the atmosphere and leaves a tough mastic coating which assures absolute adhesion between the jointing compound or premoulded belt and the sewer pipes.

SERVICISED EXPANSION JOINTS are a necessary protective material for walls, floors, roofs and sizeable monolithic construction generally. To prevent and control cracking; to protect against severe fractures; to prevent excessive pressures which can result only in damage—Servicised Pre-Moulded Expansion Joints are needed. The principal types are Pre-Moulded Asphalt, Cork Rubber and Sponge Rubber Expansion Joints. Servicised Pre-Moulded Expansion Joints play an important part in the preservation of many structures; some of them the larger engineering undertakings of recent years. Among other installations, Servicised furnished the heavy special expansion joints installed in the mammoth sewage disposal plant of the Sanitary District of Chicago.

CONTROLLING GRIT CHAMBER VELOCITIES*

An Adaptation of the Parshall Flume for Velocity Control Plus Flow Measurement

By STANLEY T. BARKER
Ass't. Engineer, N. Y. State Dept. of Health
Albany, New York

The problem of how best to control the velocity of flow through grit channels so as to perform their designed function of removing grit, without at times depositing organic solids with the grit, is one which has occupied the attention of many engineers.

In many of the older and larger treatment plants control of grit chamber velocity has been attained at rather large expense, by providing a considerable number of channels. Their operation involves manually varying the number of such in service so that the velocity through them approximates the desired figure of 1.0 foot per second. Another device which has been used is the proportional weir. This device permits the installation of fewer channels, but its deficiency lies in the excessive loss of head created.

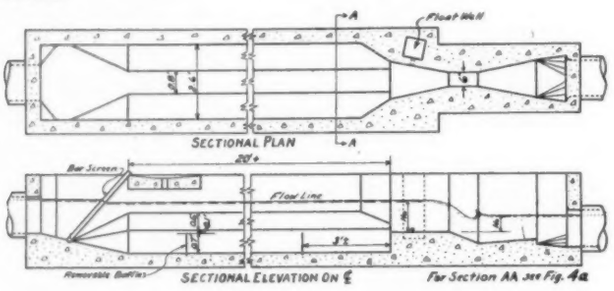


Fig. 1.—Holmes' First Parshall Flume

Another important feature in sewage treatment works design has been the question of how to measure the flow to the plant. The decision as to how best to accomplish this has involved a considerable proportional expense in some plants when Venturi meters are used, or a relatively large loss of head if weirs or orifices are used. Also, the readings of weirs and orifices, when measuring sewage flows, are subject to inaccuracies caused by the deposition of sewage solids in the channel behind the measuring device, or by material catching on the weir crest or in the orifice.

The Parshall Flume a Worthy Device

It appears that the relatively inexpensive combination of grit channels with a Parshall flume, which was devised by Mr. Glenn D. Holmes, consulting engineer of Syracuse, is worthy of especial consideration.

This combination of a Parshall flume and properly proportioned grit channels provides both the desired close control of the velocity in the grit channel and also accurate measurements of flow. It has been also demonstrated that both of these desiderata may be realized with a minimum loss of head and at relatively low construction costs. Two highly important design considerations in small plants particularly.

Such grit channel and Parshall flume combinations have been installed in a number of sewage treatment works constructed in New York State. It may be helpful to other engineers if several suggested designs for these combinations are presented, with sufficient explanations so that modified designs may be developed to suit special cases.

***Note. — The reader should also refer to three articles dealing with "Grit Removal" in the Magazine Section of this issue.—Ed.**

Such grit channel and Parshall flume combinations have been installed in a number of sewage treatment works constructed in New York State. It may be helpful to other engineers if several suggested designs for these combinations are presented, with sufficient explanations so that modified designs may be developed to suit special cases.

Suggested Designs

Figure 1 illustrates the grit channel—Parshall flume combination embodying the ideas developed by Mr. Holmes at Newark. The bar screen or a comminutor, may precede the grit channel, or the comminutor or a mechanically cleaned bar screen may follow the flume if they are so installed and operated that the flow is never backed up sufficiently to submerge the flume to an extent which will affect its accuracy in measuring flow.

This question of submergence is very important if the flume is constructed as shown in Fig. 1 and 2, with only a single float well, since if the ratio between (Hb) and (Ha) at any rate of flow exceeds .50 for the 6" flume, .60 for the 9" flume, and about .70 for the 12" or larger flumes, the single-float type of registering device will not register the flow accurately.

Figure 3 gives discharge curves for 6", 9", 12", 18" and 24" Parshall flumes which are plotted from the data in Bulletin No. 423 of the Colorado Experiment Station. From the shape of the curves it is apparent that the discharge per unit of cross sectional area of the flume is greater for large depths in the flume than for the relatively shallow depths. Therefore, the width of the grit channel must *increase with the depth,* to allow for the larger rate of discharge.

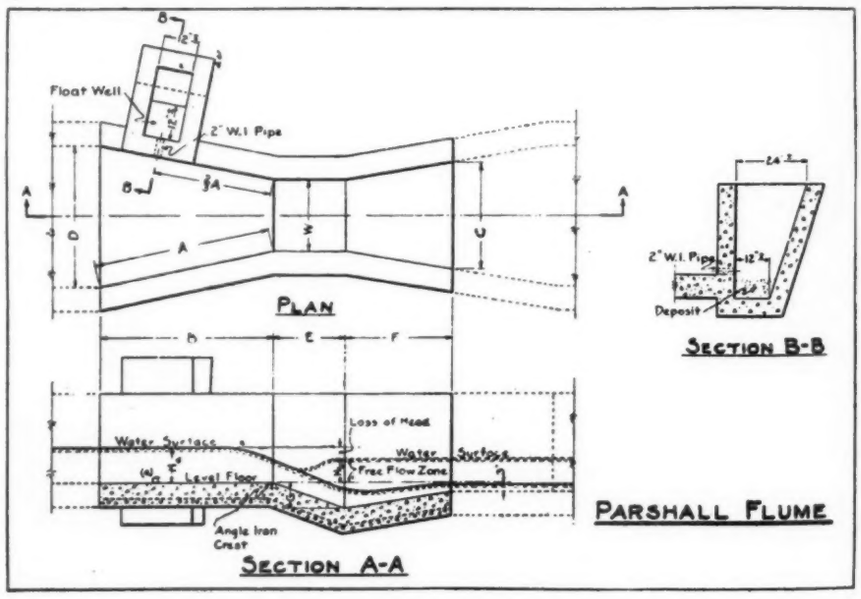


Fig. 2.—Parshall Flume in Plan and Section
(From "The Parshall Flume and Its Application to Sewage Works" by Norman C. Wittwer—W. W. & S., July, 1936, and Reprinted on page 297 of the 1939 Reference and Data Issue of this magazine.)

Flume Dimensions

For the convenience of engineers who may not have the above mentioned Parshall flume bulletin at hand, Fig 2, which is Wittwer's reproduced from the July, 1936, issue of *Water Works and Sewerage*, is here presented together with Table 1. These reveal the dimensions of the above sizes of flumes. The 18" flume is not a standard Parshall flume, and the dimensions and discharge values have been determined by interpolating between Parshall's values for 12" and 24" flumes. Since both the 12" and 24" flumes use the same free discharge formula, (in which the width appears to the first power) it seems entirely proper to conclude that the discharge of an 18" flume can be interpolated from the tabulated discharges of the 12" and 24" sizes.

It is felt that 6, 9, 12, 18 and 24 inch Parshall flumes cover the range of flows which need be considered, since if the flow is larger than can be measured properly by a 24" Parshall flume, the treatment plant is probably so large that some formform of mechanically cleaned grit channels and grit washing device will be installed. And with the provision of grit washing equipment the accurate control of the velocity in the grit channels is not so important. However, there is nothing to prevent adapting this combination of a gri tchannel and Parshall flume to the use of mechanical equipment such as drag scrapers or the like.

Depth-Velocity Ratios

Grit channel cross-sections have been designed for the above mentioned flume sizes and Table 2 shows the velocities that may be expected in the grit channels shown in Figs. 4 a, b, c, d and e, for the different depths in the flume and grit channels. The channel width, and slopes of the side walls may be varied, of course, to produce other velocities if it should deem desirable to do so. The sloping walls may be continued to a greater width before beginning the vertical walls, if a very wide variation in flows is to be expected, but it is felt that the grit channels shown will provide for the usual ranges in flow in any usual sewage treatment works. In some cases, the width of the grit channels could be decreased without seriously affecting their performance. This, the designer can decide from a study of Table 2.

Of course, a theoretically perfect channel section would have curved side walls, but these would be expensive to construct and it is felt that cross-sections similar to those shown in the suggested designs will be much more satisfactory to construct, and will give velocities close enough to the desired figure of 1 foot per second to accomplish the intended purpose.

Flexibility and Economy

For a sewage treatment works with a 6" flume and where the sewage is supposed to contain no storm water, a single grit channel is usually satisfactory and adequate, but where the flow requires a 9" flume or larger, it may be desirable to have at least two channels. Fig. 4b shows a suggested design to be used with a 9" flume, and if two channels are provided and used alternately, each should be of the size shown. However, a more economical design would be to divide the cross sectional area shown in Fig. 4b between two channels, each having vertical dimensions equal to those in Figure 4b but with horizontal dimensions half of those shown. This would permit steepening the slope of the side walls. Such will be desirable, in that it will lessen construction costs and decrease the possibility of grit or debris lodging on the sloping walls and having to be squeegeed to the sump.

TABLE I. DIMENSIONS OF PARSHALL MEASURING FLUMES

Letters refer to Fig. 2

Throat Width W	A ft. in.	⅔A ft. in.	B ft. in.	C ft. in.	D ft. in.	E ft. in.	F ft. in.	G in.
6"	2-3⅞	1-4⅝	2-0	1-3½	1-3½	1-0	2-0	4½
9"	2-10⅝	1-11⅛	2-10	1-3	1-10⅝	1-0	1-6	4½
12"	4-6	3-0	4-4⅜	2-0	2-9¼	2-0	3-0	9
18"	4-9	3-2	4-7⅜	2-6	3-4⅜	2-0	3-0	9
24"	5-0	3-4	4-10⅜	3-0	3-11½	2-0	3-0	9

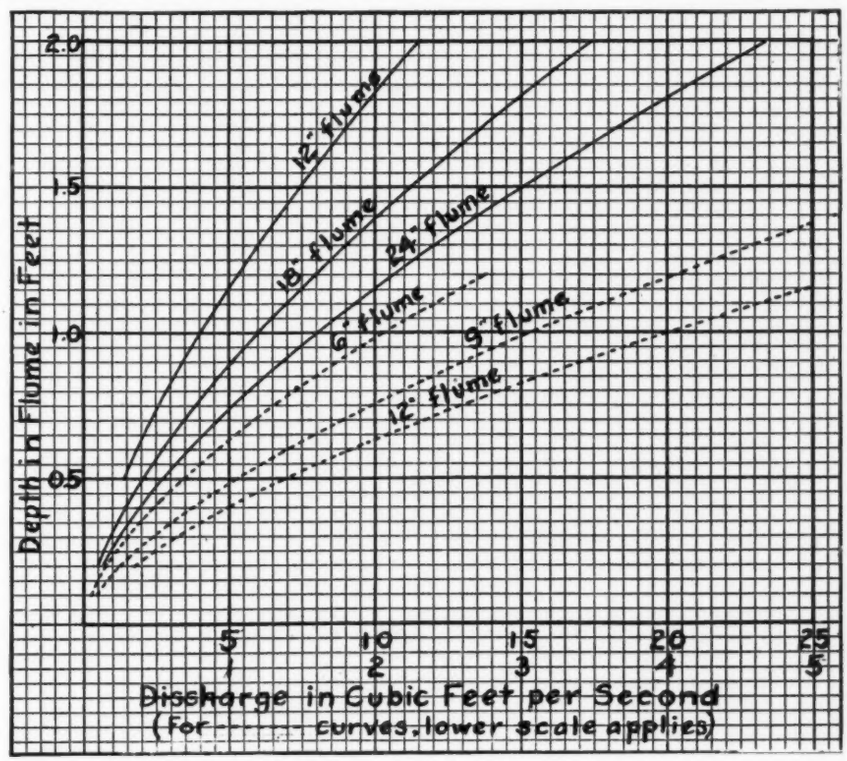


Fig. 3.—Discharge Curves for Parshall Flumes

TABLE 2 DISCHARGE AND VELOCITY IN GRIT CHANNELS HAVING DIMENSIONS SHOWN IN FIG. 4

Depth in Flume	6" Flume		9" Flume		12" Flume		18" Flume		24" Flume	
	M.G.D.	ft/sec	M.G.D.	ft/sec	M.G.D.	ft/sec	M.G.D.	ft/sec	M.G.D.	ft/sec
0.1 ft.	.03	.63	.66	.60	.....	.....	.....	.....	.....	.....
0.2	.10	.91	.16	.83	.23	.75	.33	.70	.43	.65
0.3	.21	1.03	.32	.96	.41	.86	.61	.80	.80	.73
0.4	.31	1.06	.49	1.04	.64	.93	.94	.89	1.25	.85
0.5	.45	1.08	.68	1.07	.90	1.00	1.21	.96	1.77	.91
0.6	.60	1.08	.91	1.10	1.19	1.03	1.77	1.00	2.34	.96
0.7	.76	1.06	1.15	1.12	1.51	1.07	2.25	1.03	2.98	1.00
0.8	.94	1.07	1.41	1.13	1.84	1.09	2.76	1.06	3.66	1.03
0.9	1.13	1.08	1.69	1.13	2.21	1.10	3.30	1.08	4.70	1.05
1.0	1.33	1.10	1.99	1.13	2.59	1.11	3.88	1.09	5.18	1.07
1.1	1.56	1.12	2.30	1.13	2.99	1.11	4.49	1.10	5.99	1.08
1.2	1.78	1.14	2.62	1.12	3.42	1.12	5.14	1.11	6.87	1.10
1.3	.....	.....	2.98	1.12	3.85	1.12	5.82	1.11	7.77	1.10
1.4	.....	.....	3.33	1.11	4.32	1.13	6.42	1.12	8.72	1.10
1.5	.....	.....	.....	.....	4.79	1.12	7.25	1.12	9.71	1.11
1.6	.....	.....	.....	.....	5.29	1.12	8.02	1.12	10.75	1.11
1.7	.....	.....	.....	.....	5.80	1.12	9.11	1.12	11.80	1.12
1.8	.....	.....	.....	.....	6.33	1.12	9.61	1.12	12.90	1.12
1.9	.....	.....	.....	.....	6.87	1.12	10.45	1.12	14.05	1.12
2.0	.....	.....	.....	.....	7.43	1.12	11.32	1.12	15.17	1.12

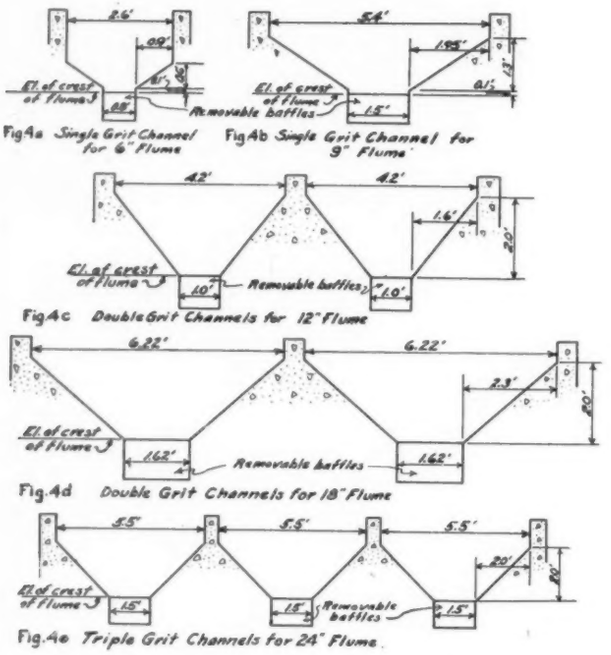


Fig. 4.—Suggested Dimension Details for Grit Channel Designs

The slope of the side walls of the grit channel shown in Fig. 4b is 1½ on 1, and single channels for the larger flumes would have side wall slopes as flat as 2 or 3 on 1, so for this reason alone it is desirable to provide two or more channels for use together, so as to make it possible to keep the slopes down to approximately 1 on 1.

With a single grit channel, the plant operator would have to scrape the grit from below the flowing sewage, but this should not be a severe hardship at a small plant where the quantity of grit is not great. Of course, if the grit is expected to be deposited in large amounts, two or more channels should be provided at even the smallest plants so one can be cut out for cleaning.

In the case of plants requiring 12" or 18" flumes it would seem necessary to install at least two grit channels for continuous service and the cross sections shown in Figure 4c and d are suggested. And for a flow requiring a 24" flume it would seem advisable to install 3 channels for continuous use, which would then have the dimensions shown in Figure 4e.

Depth and Length of Sump

If, for any reason, the plant is designed so the two channels are to be operated alternately, the approach to the flume should be given consideration and a long enough approach channel provided so the flow will enter the flume in a reasonably straight line and not pile up on one side of the upstream channel of the flume.

The depth of the grit sump will be governed by the designer's idea of the quantity of grit that may be expected, but for plants where the flow is supposed to contain no storm water an 8" or 12" depth of sump should be adequate.

Similarly, the decision as to what length of grit channel to provide requires considerable judgment as to the amount of grit to be expected, but it would appear that in a small plant treating supposedly only sanitary sewage a length of 20 feet is sufficient. In the larger plants, having a normal depth of flow in the grit channels of 1 foot or more, lengths of 30 to 40 feet would seem to be necessary to take out all the grit of troublesome size.

To keep the grit sump from serving as part of the flowing through compartment, Mr. Holmes provided a grating, with a relatively wide spacing of bars between the flowing through compartment and the sump, as shown in Figure 5. It is stated that this arrangement works satisfactorily at Newark. The same end may be attained by providing removable metal baffles at intervals, across the grit sump (Figure 1).

Why Grit Chambers?

Experience with a number of sewage treatment works receiving supposedly sanitary sewage has demonstrated that sand and grit more or less frequently gets into sewer systems, and has proved hard on pumps and very undesirable in causing sludge to pack and refuse to move from digestion units.

Since the above type of grit channels can be provided at so small a cost, it is felt that they should be more universally employed in the original design. In addition to grit removal, the dual function of flow measurement is provided by such units.

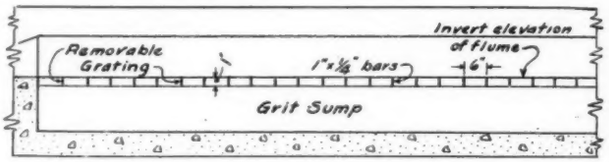
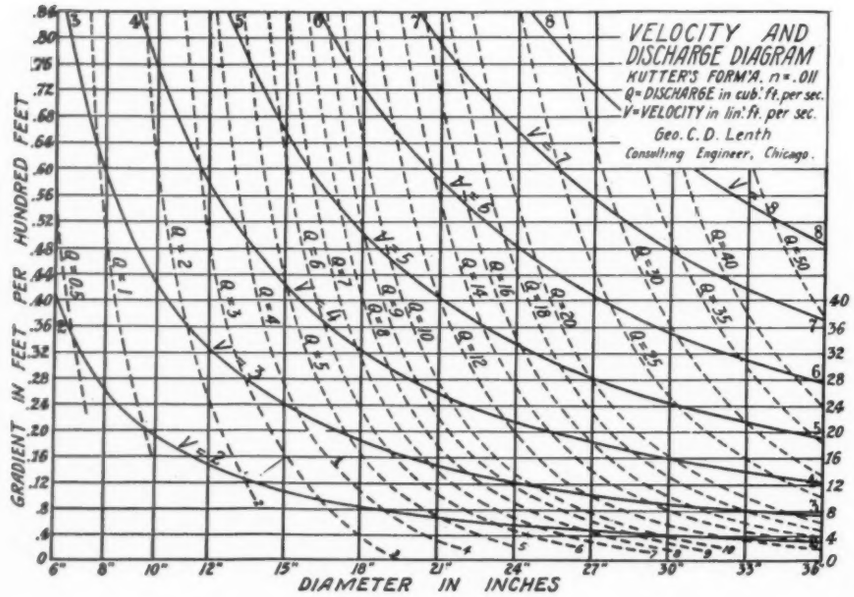


Fig. 5.—Sump Design Beneath Channel at Newark, N. Y. Note removable bar grate separation of channel and sumps

Velocity and Discharge Diagram for Vitrified Clay Sewer Pipe


VELOCITY AND DISCHARGE DIAGRAM
KUTTER'S FORM'A. n=.011
Q=DISCHARGE in cub.'ft. per sec.
V=VELOCITY in lin.'ft. per sec.
Geo. C. D. Lenth
Consulting Engineer, Chicago.
GRADIENT IN FEET PER HUNDRED FEET
DIAMETER IN INCHES
6" 8" 10" 12" 15" 18" 21" 24" 27" 30" 33" 36"

Example: Assume 12 cu. ft. per sec. as the flow to be handled. The gradient for instance, to be a 0.2 ft. per 100 ft. run. Follow to right from gradient figure 0.20 on left until Q12 dotted line is intersected. The vertical line found at that point indicates that a 24 inch sewer is required. Also from the nearest velocity curve V.4 at the intersection it is revealed that the velocity will be 3.8 ft. at full or half full flow.

(Courtesy, Clay Products Assn.)

BAILEY METER COMPANY

1072 Ivanhoe Road, CLEVELAND, OHIO

BOSTON NEW YORK ST. PAUL BUFFALO KANSAS CITY PITTSBURGH HOUSTON ERIE DENVER CINCINNATI SAN FRANCISCO CHICAGO MILWAUKEE

BAILEY METER COMPANY LIMITED, Montreal, Canada

METERS, GAGES and CONTROLLERS for SEWAGE TREATMENT and WATER SUPPLY

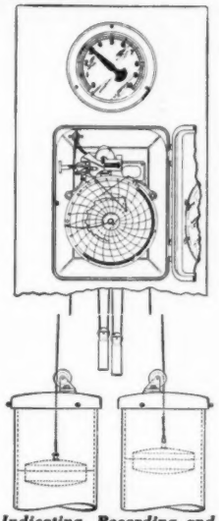
STANDARD BAILEY REGISTERS

Open Float Type Meters—The flow of sewage, sludge, dirty water or other liquids in pipe lines is accurately measured by the Bailey Float Type Meter using a Venturi Tube, flow nozzle or orifice as the primary producing device.

This meter is of the open float tube type with differential gearing and cam designed so that the register operates in direct proportion to the rate of flow.

Standard Bailey indicating, recording and integrating instruments are used; charts being 12" in diameter and uniformly graduated. These instruments may be either wall or panel mounted and may be furnished on self-supporting panels if desired.

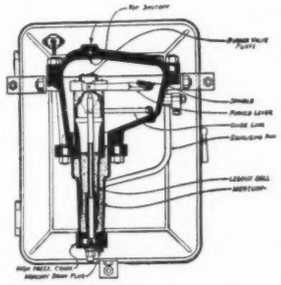
Bailey float type meters are simple, sturdy, neat-appearing and extremely flexible. Capacities may be changed by simple adjustments within the register and remote instruments can be operated from the main register if desired.



Indicating, Recording and Integrating open float tube type Register.

Bailey Flume Meters—Surprising low head losses result from the measurement of water or sewage in open channels when Bailey Flume Meters are used. These simple self-cleaning meters indicate, record and integrate on standard Bailey registers. Instruments may be placed in remote locations by the addition of the Bailey Synchro-Meter transmission system.

Bailey Weir Meter—Highly accurate results in the measurement of sewage or water flowing in open channels are obtained by the use of the Bailey Weir Meter.



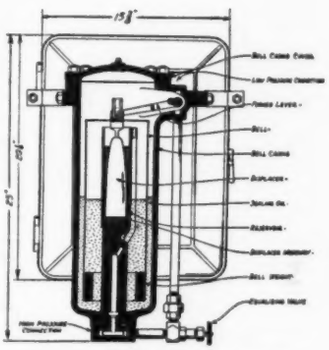
Section through flow mechanism of Ledoux Bell type Register.

Complete flexibility in the location of the standard Bailey registers of this meter may be provided by the Bailey Synchro-Meter transmission system.

Bailey Fluid Meter—The flow of steam, liquids and gases in pipe lines at high or low pressures can be accurately measured by the Bailey Fluid Meter. A Venturi Tube, flow nozzle, or orifice is used as the differential producing device and the meter indicates, records and integrates on the standard Bailey register previously described. Remote recorders may be provided by Bailey Synchro-Meter transmission which operates electrically on alternating current.

In addition to the rate of flow, this meter may also record pressure, temperature or liquid level on the same chart.

Described in bulletin No. 301.



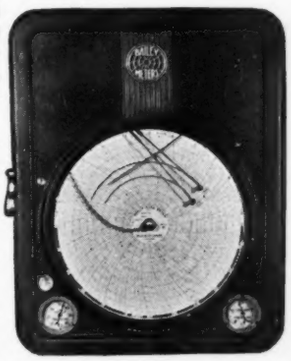
Section through flow mechanism of Air Meter

Air Meters—These meters measure Air Flow in main lines and in individual lines to aeration tanks.

The register is similar in appearance to the Ledoux bell type, and the flow mechanism is designed to operate on a maximum differential pressure of 8-in. of water. *Described in bulletin No.* 301.

Remote Registers—Bailey Telemetering systems make it possible to operate remote indicating, recording or integrating registers, which may be installed at a distance from the direct connected unit. These registers may measure flow in individual lines, total flow, liquid level, pressure and other factors.

Venturi Tubes—Standard Bailey Designs include a complete range of Venturi tubes and other primary elements suited to the measurement of sewage, sludge and water. The selection of a suitable primary element is governed by such factors as capacity required, type of flanges, pressure loss allowable and character of fluid to be metered.



Bailey Recorder—Controller.

Controllers—Bailey Controllers utilize standard Bailey Meters and Recorders as the basic measurement source for the automatic control of factors, such as flow, ratio, pressure and liquid level. They are operated by compressed air at approximately 35 lbs. pressure and match perfectly with other Bailey gages and registers.

Bailey control is fully automatic, dependable and exceptionally flexible. *Ask for Bulletin No.* 101.

Bailey Registers measuring Sewage, Sludge and Air in an operating gallery at Easterly Sewage Treatment Works, Cleveland, Ohio.

CHICAGO PUMP COMPANY

2349 Wolfram St., CHICAGO, ILLINOIS

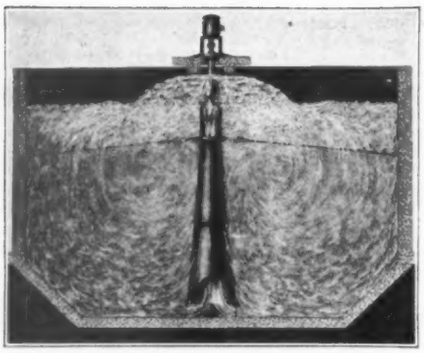


Fig. 2312—Mechanical Aerator

Flora, Ill., installation giving 98% reduction of domestic sewage of 570 p.p.m., 24-hr. average (5-day) B.O.D. Power consumption of 0.337 Kilowatt hours per lb. B.O.D. reduced, measured on primary effluent of 330 p.p.m. B.O.D. Ask for Bulletin 128-L.

Chicago Pump Co. also manufactures the Combination Aerator - Clarifier which performs straight aeration and clarification simultaneously in a single tank. Ask for Bulletin 128-K.

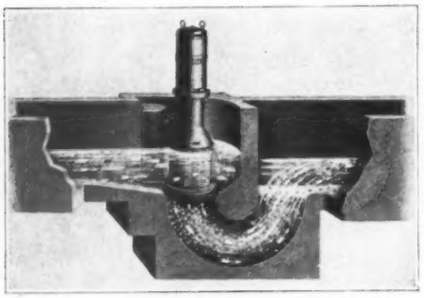
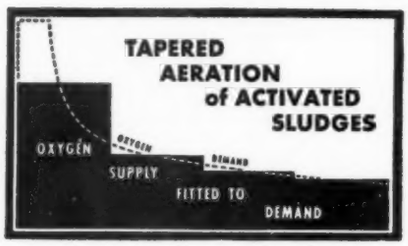
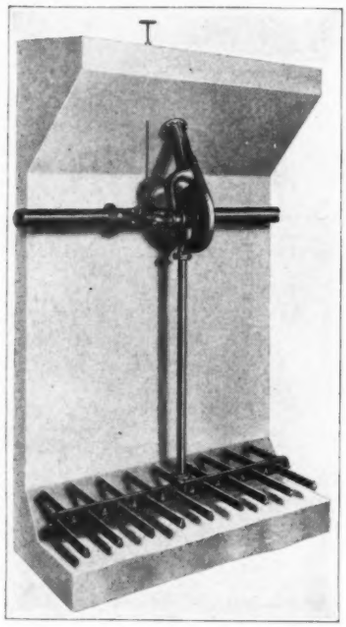
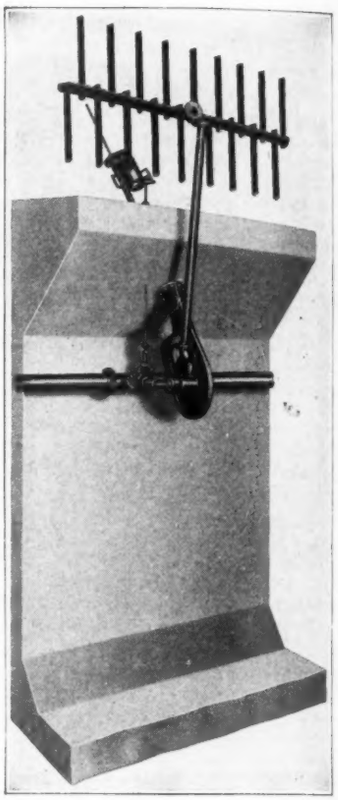


Fig. 2202—Comminutor

Eliminates screenings and screenings disposal—No burial; No incineration. Cuts coarse sewage matter into small settleable solids without removal from the channel.







Figs. 2905 (left) and 2910 (right)—Swing Diffusers

Controlled aeration for the Activated Sludge Process. Diffuser tube assembly can be raised to tank walk. Simple regulation of air supply from tank walk. Tube cleaning without dewatering tanks or interrupting operation. Ask for Bulletin 175.

Fig. 2504—Vertical Open-shaft Non-Clog Pump

Universal Flexible Couplings in shaft compensate for misalignment. Ask for Bulletin 126.

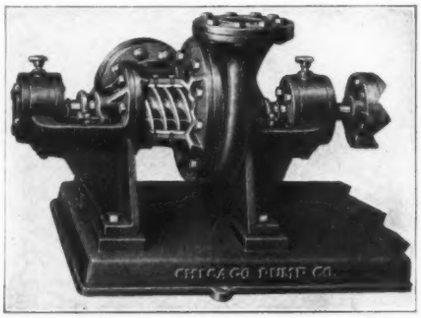


Fig. 1860—Scru-Peller Primary Sludge Pump

Screw conveyor in the suction ahead of the impeller. Stellited cutters prevent clogging. The capacity can be varied instantly. Ask for Bulletin 190.

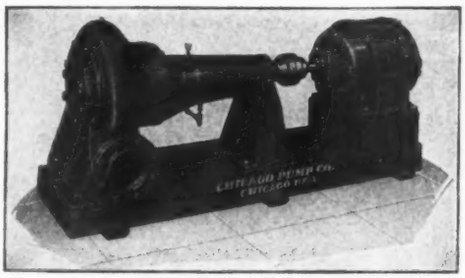


Fig. 1774—Horizontal Non-Clog Pump

Being mounted directly on base prevents pump being pulled out of alignment by long lines of piping. Ask for Bulletin 127.

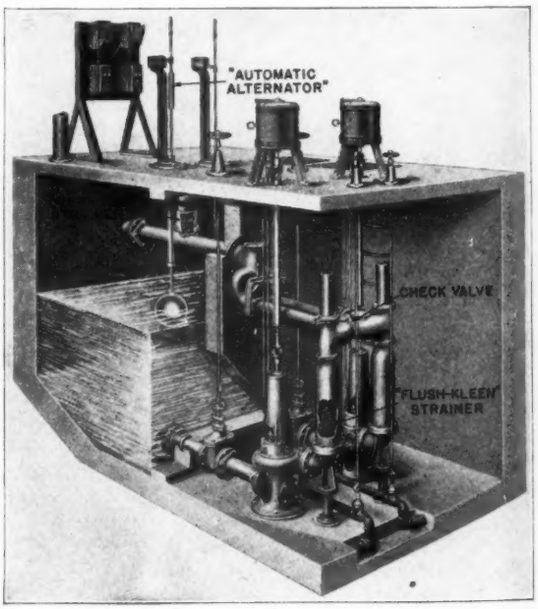


Fig. 2038—Flush-Kleen Sewage Pumping Station

Requires no attention. NEVER CLOGS. Automatically backwashes strainer. Keeps solids from basin and pumps. Impeller handles water, only. Coarse sewage matter is stopped by Flush-Keen strainer and is flushed out through discharge pipe. Check valve prevents discharging back through inlet line. Ask for Bulletin 122.

SEWAGE AND SLUDGE PUMPING

By HENRY RYON
Senior Engineer
State Department of Public Works, Albany, N. Y.

Part I—Sewage Pumping

During the past several years a very marked improvement has been made in the methods of pumping sewage and sewage sludge, and special pumps have been developed for this service. Only a few years ago, however, practically all sewage was lifted with pumps designed primarily for handling water.

The centrifugal dredging pump driven either by a steam engine or an electric motor was used with a fair degree of success at many stations. While this pump would handle sand and gravel satisfactorily, rags would wrap themselves around the impeller and necessitate frequent cleaning of the pump either through hand holes in the volute or by the removal of the side of the case. It was not very efficient and the head was limited. The smaller and higher speed centrifugal pump, used successfully for pumping water, gave more trouble, due to clogging, when used for pumping sewage, than the dredging pump.

Reciprocating pumps were used in many cases. These pumps clogged about as easily as the centrifugal pumps; and, if there were any sand or grit in the sewage, gave trouble due to the scoring of cylinders. At one or two large stations the crank and fly wheel pump was used and operated satisfactorily principally because of its large size. The ordinary duplex steam pump served in a few cases. The single acting triplex pump, equipped with ball valves, although not entirely free from clogging, proved to be the most satisfactory of the reciprocating pumps and was used, and is still being used, successfully for pumping both sewage and sludge. Its cost is, however, greater than that of a centrifugal pump and it is rather noisy. It is worth noting that the design of the most modern reciprocating sludge pumps have apparently been copied from the old single acting triplex pump.

At almost all of the old pumping stations the sewage was passed through bar or mesh screens to remove the rags and other solids from it before it reached the pumps. The cleaning of the screens always proved a laborious and unpleasant task, and did not entirely do away with the necessity of cleaning the pumps.

The Pneumatic Ejector

In order to eliminate the trouble of cleaning screens and pumps, the pneumatic or compressed air ejector was developed. This device, which was first used about fifty years ago, operates by allowing the sewage to flow into an iron or steel chamber and, when the chamber is full, automatically admits compressed air above the sewage thus forcing it out through the discharge line. The mechanism operates very successfully, and stories are told of ejectors having been lost for several years and when rediscovered were found to be operating satisfactorily. It requires, however, air compressors, air tanks, and other appurtenances which make the first cost and also the maintenance expensive. In addition to this, the efficiency is very low. The overall or wire to water efficiency when the compressors are operated by electricity vary generally from 10 to 20 per cent. At present, due to the improvements in the design of centrifugal pumps, ejectors are being used less and less except in the very small stations or for sludge and screenings handling.

Pump Impellers

The improvement in the centrifugal sewage pumps has been largely in the design of the impellers or runners. There are, in general, two types of pump impellers, the open and the closed. The open impeller gives larger water ways with the same size casing, but solids clog between the impeller and the casing and rags wrap around the impeller blades. Increasing the clearances to reduce clogging, of course, reduces the efficiency and does not prevent rags from stopping the flow. Open impellers, generally with only two blades, serve well in small sump pumps and also in sewage pumps of small capacities where a closed impeller small enough to give the desired capacity would not pass solids of any size. In most cases, however, the closed or semi-enclosed impeller is to be preferred.

In the design of closed impellers for handling sewage, the water passages have been made wider than in water pumps, all sharp edges and turns have been carefully avoided, thus reducing the chance of clogging to a minimum. As a general rule pumps with impellers of this type will pass solids having diameters about one pipe size smaller than the size of the pump. One manufacturer is producing a pump with a worm feed to force the solids to the impeller of the pump and also cut and crush them against hard steel bars running longitudinally of the screw case. Pumps of this type are giving satisfactory service in several western stations. A rather unique impeller is used in some English pumps. The impeller is open on the suction side and the blades are considerably wider at the shaft than at their ends. The edges of the blades pass very close to bars set on the inside of the case and macerate the solids entering the pump.

It is customary to require the impellers of the pumps to be made of bronze but with ordinary sewage there seems to be no advantage in the use of bronze as compared with that of cast iron. A few pumps have been installed having cast iron impellers coated with enamel and they are said to be giving satisfactory results. The manufacturers claim a slightly higher efficiency for this impeller than can be obtained with the bare metal impeller.

Submerged Vertical Pumps

For the smaller installations probably the submerged vertical centrifugal pump is the most commonly used. The sump may be made of cast iron or steel or may be of concrete. The motor and pump are both supported on a removable iron cover so that the pump can be lifted out of the sump for cleaning and repairs. Enough head room must, of course, be provided to allow the suction to clear the top of the sump when the pump is lifted out. It is also desirable that the discharge be brought up through the same plate so that it may be easily disconnected. In unheated pump houses, however, it is sometimes impossible to do this without danger of the sewage in the discharge line freezing. Where short separate discharges can be used, freezing can be avoided by omitting the check valves and allowing the sewage in the discharge pipe to flow back into the sump after each discharge. If screens are to be omitted it is usually advisable to provide a pump not smaller than 3 inches in size. Such a pump will have a capacity of from 50 to 300 gallons per minute, depending upon design of the impeller and the speed of the motor.

Float Controls

Sewage pumps are usually automatic in operation and the arrangement of the float control deserves more attention than it generally receives. The float may be connected to the electric switch either by a push rod or by a chain running over pulleys with a counterweight to balance the float. Either method operates satisfactorily if properly arranged. Floats that hang unprotected in the sump are apt to be moved sideways by the motion of the sewage causing the chain or rod to bind, or the rod to bend, making the float inoperative. In some designs the rod has a guide at the bottom to prevent such motion, but if the rod sticks in the guide or leaves the guide its inaccessible location makes it very difficult to repair. The lever float, sometimes used, has generally proved very unsatisfactory for sewage because rags are apt to collect on the lever and prevent its operation. As in the case just mentioned it is generally very difficult to reach such a float to repair or adjust it. The best design is one in which the float is arranged in a tube to guide and protect it and a removable cover plate provided over the tube so that the float can be readily lifted out.

Pumps in Separate Dry Wells

For the larger pump stations, and even in the small stations when the conditions will permit, the installation of the pumps in a separate dry well makes the most satisfactory arrangement. This leaves the pumps and their appurtenances accessible for repairs and adjustment. The pumps may be either vertical or horizontal. The vertical pumps have the advantage of requiring a smaller pit and of keeping all electrical equipment above ground and free from danger of flooding, while on the other hand the horizontal pumps are easier to keep in adjustment and alignment. If the pit is deep, one or more guide bearings will probably be required on the shafts of vertical pumps as it is necessary to divide the shafts into lengths of not more than 8 or 10 feet to prevent vibration. I-beams are usually set across the pit to carry these bearings, but it is often difficult to set these beams so as to get a perfect alignment of the shaft. In order to avoid this difficulty, several manufacturers are building steel lattice frames extending from the motor to the pump. The pump and motor can then be aligned at the factory with very satisfactory results. In some cases the motor, shaft and pump have been attached to a heavy channel, aligned at the factory, and shipped as a unit.

With the pumps in a separate dry well it will usually be necessary to provide some means for removing seepage from the well. This may be done with a separate automatic sump pump, or, if a cheaper installation is desired, a small valved connection may be made from the suction of one of the main pumps to a sump and the sump emptied at intervals by closing the main suction valve and opening the connection to the sump.

Design of Suction Well

The shape of the bottom of the suction or wet well is of considerable importance. If it is left flat, solids will collect in the bottom and ferment giving rise to unsatisfactory conditions. The floor of the wet well should have a steep slope toward the pump suctions.

In some cases where the sewage is warm and contains considerable grease, trouble has been experienced due to the grease congealing on the walls of the well and then breaking loose in large pieces and entering the pumps and clogging them. The openings in the impellers of 4-inch horizontal sewage pumps have been stopped several times by this cause.

Bearings and Glands

There does not appear to be very much choice in regard to the type of bearings used, ball bearings and sleeve bearings seem to serve equally well provided they are properly oiled. Ball bearings are, however, usually provided to take the thrust or to carry the weight of the impeller of a vertical pump. The part of the shaft that passes through the stuffing box should be of bronze or covered with a bronze sleeve otherwise difficulty will be experienced in keeping the packing in condition. This stuffing box is usually provided with a water seal, although grease seals and special devices are sometimes used. In water pumps the water for the seal is usually taken from the volute of the pump. With sewage pumps, however, this is not advisable for the solids in the sewage are apt to clog the small passages and also because the grit in the sewage will reach the packing and cut the pump shaft. To avoid the possibility of the pollution of the clear water with sewage, the water must usually be taken from a constant level tank supplied from the water lines and not directly from the lines themselves. With double suction and open impeller pumps, if there is a suction lift, there will probably be vacuum on the pump side of the stuffing box and the water seal serves to prevent the entrance of air. With end suction pumps, with enclosed or semi-enclosed impellers, there may be a pressure on the pump side of the stuffing box. The water seal then serves to prevent the grit in the sewage from reaching the packing and cutting the shaft. The pressure on the water seal should of course be greater than the sewage pressure.

Centrifugal sewage pumps will operate satisfactorily if set as high as 15 feet or even a little more above the sewage level, but in such cases special priming devices must be provided for the ordinary method of priming, by filling the suction from the discharge line, cannot be used because it is inadvisable to attach a foot valve to the bottom of the suction. While special priming devices can be used, it is better, if possible, to locate the pumps below the level.

Efficiency and Head

The non-clogging centrifugal pumps will generally give over all efficiencies varying from 35 per cent for the smaller sizes to 65 per cent for the larger pumps. The lift of sewage pumps is usually low and most of the pumps are designed for heads under 40 feet but pumps can be obtained that will lift sewage against heads as high as 75 or even 100 feet. Beyond this head two stages are needed, but the ordinary type of multistage pump used for water cannot be used because of the many sharp turns and the narrowness of the water passages. At a station where it was necessary to raise sewage 180 feet, two pumps connected in series on the same base, with the motor between them, have been used successfully. The overall efficiency of the unit was found on test to be 35 per cent.

Hydraulic Characteristics of Centrifugal Pumps

With centrifugal pumps, careful attention must be given to the hydraulic characteristics of the pumps in designing a pumping station, particularly if the discharge line is of any considerable length.

If an engineer desires a pump to deliver 300 gallons per minute against a head of 20 feet he is very apt to add a little to the head for safety and specify that the pump shall deliver 300 gallons a minute against a head of say 21 feet. A typical 4-inch pump will meet these specifications almost exactly, and will require about 2¼ horsepower to operate it and, a 3-horsepower motor will serve satisfactorily. If, after installation, it is found that the actual head is only 18 feet instead of 21 feet, due to some unforeseen condition or due to the fact that the engineer figured his friction for 10 year old pipe and the pipe is actually new pipe, this pump will deliver 600 gallons per minute instead of 300 gallons per minute and will require 3½ horsepower. The 3-horsepower motor will in that case be overloaded. Conditions similar to this occur very frequently and it is best in all cases to require the motor to be of sufficient size to operate the pump without overheating at any head between the maximum and zero.

When two or more pumps are connected to the same discharge line, the reverse condition often occurs. If two pumps, having the characteristics mentioned above, are connected to a single discharge line, one pump operating alone will discharge 300 gallons per minute. When both pumps are put in operation the friction loss in the discharge line will of course increase. With the particular 4-inch pump just mentioned, if this increase is only about 1½ feet (from 21.0 feet to 22.6 feet) the discharge of each pump will be reduced to 200 gallons a minute or the total discharge of the two pumps will be about 400 gallons per minute or only slightly greater than the discharge of one pump. For this reason it is often found desirable, especially with long discharge lines, to arrange the controls so that one pump will shut off entirely and the second pump, designed for a larger capacity and a little higher head, will start when the sewage flow exceeds the capacity of the first pump.

Multispeed motors are sometimes used to meet these conditions but such motors operate only at certain fixed speeds and it is generally difficult to design the pumps to obtain the desired capacities at these motor speeds. Any desired speed may be obtained by using variable speed motors, but if this is done the losses in the resistances greatly reduce the overall efficiency of the pumping equipment.

At the Harlem Valley State Hospital pumping station which contains 8 4-inch 450 gallon per minute pumps, a special arrangement was used. As each additional pump starts the friction loss in the discharge line increases approximately 6 inches. The controlling float and float switches are so arranged that as each additional pump starts the sewage level in the suction well is automatically allowed to rise 6 inches. Thereby, the total head, and consequently the discharge of each pump, always remains the same and has proved a distinct advantage.

Suction Line Difficulties

There are several matters in connection with the arrangement of centrifugal pump suction lines, particularly where there is some suction lift, which, while they seem very simple, have caused engineers and operators considerable trouble. There must be no high point in any suction line where air or sewage gases may accumulate. When the pump is started the accumulated air will expand, flow to the pump, and stop its operation. The reducer at the pump must for this reason always be an eccentric reducer with the flat side up. Connections to a

common suction header must for the same reason be made at the top of the header and not at the center of the side. In some extreme cases it has even been found necessary to place the suction valves horizontally so as to avoid the accumulation of air in the bonnets. Common suctions, that is, single suction lines to which two or more pumps are connected, are a source of trouble in many cases where there is a suction lift, and wherever possible should be avoided. It is often difficult in such cases to make each pump take its share of the load. When one pump is in operation it is often impossible to start the second without shutting down the first and starting both together. A slight leak in the stuffing box of one of the idle pumps will many times admit enough air to interfere with the operation of the other pumps. Even when the pump that is not to be operated is entirely shut off, air will frequently accumulate in the riser from the common suction to that pump and will expand when the other pump or pumps are started and enter them and prevent them from operating.

Part II—Sludge Pumping

Pumps designed for moving or lifting sewage sludge may, in general, be divided into two distinct classes, displacement pumps and centrifugal pumps. Since these two classes differ radically in their design and operation and present entirely different problems for those in charge of them, it is necessary to consider them separately. The advantages and disadvantages of each class are matters which engineers and operators are not entirely agreed upon. Displacement pumps are unquestionably more easily primed than centrifugal pumps when there is a suction lift and will probably handle small quantities of sludge more readily than centrifugal pumps, but beyond this it is doubtful whether the advocates of either class will admit the superiority of the other.

Displacement Pumps

The modern displacement pumps used for handling sludge are always of the single acting reciprocating type, and are usually electric motor driven plunger pumps having one, two or more cylinders. The makes most commonly used generally have cylinders about ten inches in diameter and strokes adjustable from about two to five inches. The pumps are connected to the motors by gears, belts or chains and the motion transmitted to the pistons by walking beams or eccentrics. Each manufacturer apparently believes that the transmission used by him is the best, but in practice there seems to be little difference.

Transmission

Certain matters in connection with the transmission are, however, of importance. If it is desired to have the pump run smoothly it is usually best to keep the speed of the main pump shaft below about thirty-five revolutions per minute. This gives a piston speed of thirty feet a minute or less, a low figure as compared with the usual figures for water pumps; but the strokes of these sludge pumps are very short and the frequency of the reversals seem to be of more importance than the actual piston speed. Pumps of this type are generally arranged so that the length of the stroke can be changed by shifting an eccentric or, which amounts to the same thing, altering the length of the crank arm. This makes it possible to obtain several different rates of discharge, but experience indicates that the use of the shorter strokes is not always entirely satisfactory. The pumps in most cases do not operate as smoothly with the short strokes as with longer ones, the slip is greater and the efficiency lower. The use of multi-speed motors and variable speed transmissions, although more expensive, afford a more satisfactory and efficient method of changing the pump capacities to suit the conditions, and where available should be used in preference to changing the length of the stroke.

Packing

Like all reciprocating pumps the sludge pumps must be packed to prevent leakage between the pistons and the cylinders, and this packing is one of the most frequent causes of trouble in the operation of the pumps. The packing may be either on the cylinder or the piston. Generally it consists of from 4 to 6 rings of ½ inch to ¾ inch packing held in place by an adjustable metal ring or gland. If the packing is too tight, scored pistons or cylinders and broken shear pins will be the result. If the packing is too soft, too loose or improperly placed it will leak, and since the pumps are outside packed this means that the pumps and probably the floor around them will soon be covered with sludge which does not add to the attractiveness of any sewage treatment plant. Opinions differ as to the most satisfactory type of packing. Generally a square braided flax packing serves as well as any. A graphited packing may be desirable to prevent unsatisfactory conditions due to rust where the pumps stand idle for a considerable time. Rawhide packing is satisfactory but does not seem to be necessary except with certain chemicals. The packing must fit and must be properly placed. In cutting the packing it is well to use a template into which a piece of packing exactly the length of one ring can be fitted. In this way each ring will have the same length and the same bevel. The method of oiling the packing varies with the make of the pump. Generally it is found that a fairly heavy oil such as a good grade of cylinder oil gives the best results. Oils known as "500 W" and "Marine Pump Oil" are in common use. A light oil disappears very rapidly. Under continuous operation the packing will usually last about 3 months, but under intermittent operation it may last a year or two. Manufacturers have recently been giving more attention to the finishing of the pistons and cylinders, in some cases grinding them. This has made it easier for operators to keep sludge from leaking between the pistons and cylinders but has not done away with the necessity for careful packing.

Valves

Each cylinder of a reciprocating pump necessarily has an inlet valve and a discharge valve. These valves may be weighted flap valves or ball valves. Each type has its advocates although at present the ball valves seem to be preferred by most operators. Spring loaded poppet valves which operate satisfactorily in water pumps obviously cannot be used for liquids containing an appreciable amount of solids. No mater which type is used the valves will require some attention from the operator. With raw sludge the valves may require cleaning from two to three times a day to two or three times a week. If the pump is handling activated or secondary tank sludge, cleaning will of course be required less frequently. Fibrous material will collect under the hinges or flap valves and rags will accumulate under ball valves holding the valves off their seats and rendering the pump inoperative. Metal flap valves wear at the hinges so that the flap will not seat properly and soon require replacement. Valves of rubber with rubber hinges clog less frequently than metal valves because of their smoother surfaces, but the rubber hinges are inclined to swell and split and it is difficult to turn them back for cleaning. Ball valves are usually of rubber moulded on an iron core. If they are to operate satisfactorily, careful attention must be given to the quality of the rubber, the balance of the valve and the weight of the core. Valves made of a poor quality of rubber will sometimes swell and stick, and cases are on record where the rubber has softened so as to allow the ball to be forced into the piping stopping the pump. The valve must balance or the ball will always seat at the same point and wear rapidly. The weight of the valve must be suitable for the conditions under which it will operate.

Pounding or Knocking

One of the most frequent complaints heard regarding the operation of reciprocating pumps is that they knock or pound. This is due to various causes. Since sludge lines are usually comparatively short, the high water hammer stresses sometimes encountered at water pumping stations are seldom of importance, but the flow of liquid in the suction and discharge lines must be stopped and started with each stroke (single cylinder pump with no air chamber), the valves must close and in doing so strike the seat, and each stroke causes a reversal of stresses in the piston, the crank and the connecting mechanism. These conditions cause pounding which cannot in all cases be entirely eliminated. The subject is too complicated to be discussed in detail here.

The stresses and pounding due to starting and stopping the flow in the discharge line can be generally alleviated by the use of an air chamber, but the air chamber must be large to be of any value. The same thing is true of the suction line, although an air chamber is not so frequently used at this point. One manufacturer provides a small air inlet valve on the suction of the pump which if properly adjusted seems to make the pump operate more smoothly, but of course somewhat reduces its capacity and efficiency.

Valve slam is sometimes due to the fact that the direction of flow through the valve reverses and acquires considerable ve-

locity before the valve closes. This velocity may then carry the valve to its seat rapidly enough to cause a heavy blow when the motion of the valve and the liquid is suddenly stopped. This reverse flow of water through the valve is of course slippage and reduces the efficiency of the pump as well as causing valve slam. The valve should, for these reasons, be heavy enough and so arranged as to close as quickly as possible, and yet not interfere with the operation of the pumper by reducing the area of the ports.

The knocks due to the reversal of stresses in the different parts of a pump are the same as those which occur in any reciprocating machine. If there is any lost motion in a main bearing, eccentric, wrist pin or other part there will be a knock each time the stresses are reversed. The remedy is obvious. All bearings must be properly adjusted and kept properly lubricated.

Centrifugal Pumps

Centrifugal pumps, if they are to handle sludge successfully, must pass solids without frequent clogging. This makes it necessary to use end suction pumps at least 4 inches in size with as few bends and sharp corners in the liquid passages as possible. The impellers usually have only two blades with long sweeping curves and are either fully enclosed or have a shroud on one side. Open impellers clog very rapidly when the liquid contains rags. Even with these precautions, it is generally desirable to have hand holes or other means of access to the interoir.

One pump manufacturing company equips its centrifugal sludge pumps with a screw to force the sludge into the pump and to macerate the solids as they enter. Pumps of this type have been in operation at a number of plants for several years. Similar devices are being made by some other manufacturers but have not as yet come into extensive use.

Capacity and Regulation

A 4-inch centrifugal pump will readily discharge 100 gallons a minute and in some cases as low as 50 gallons a minute, but if capacities below this are necessary some difficulty is apt to be experienced unless provision is made for reducing the speed below that which can be obtained by a direct connected motor. Variations in head, of course, cause variations in the capacity of a centrifugal pump and if a definite quantity of discharge is required some method must be provided to compensate for these variations. In many plants it is necessary to change the quantity of sludge delivered from time to time and provision must be made for so doing. Theoretically, throttling might accomplish these ends, but throttling is not desirable when pumping sludge. If careful adjustment of the quantity of sludge delivered is necessary the only practical method of regulations seem to be to change the speed of the pump. Variable and multi-speed motors will do this within limits but are not as satisfactory as some of the variable speed transmissions available. These transmissions, while expensive, make it possible to obtain almost any capacity within the limits of the pumps. It must not be forgotten, however, that a centrifugal pump will give its highest efficiency at one definite speed and capacity and that as the speed and capacity are changed the efficiency may fall off rapidly. This is naturally of more importance when the pumps are in continuous operation than when they are operated intermittently.

Priming and Seals

Centrifugal pumps will not handle air and when they are used careful consideration must always be given to priming and to the elimination of air pockets in the suction line. To facilitate priming, centrifugal pumps should if possible be set below the surface of the liquid in the suction well. If the pump must be set above the level of the liquid some means of priming must be provided. Foot valves which are often used with water pumps will not serve satisfactorily with pumps handling sludge. Vacuum systems are available and operate satisfactorily if kept in condition, but mean added expense of installation and more equipment for the operator to maintain.

The impeller shaft of every pump of this kind must pass through the pump casing and therefore requires a stuffing box to prevent leakage. On water pumps these stuffing boxes are provided with water seals and the water taken from the pumps. The material handled by a sludge pump is not, however, suitable for the seals and water must be obtained from some source. A direct connection to the water system cannot be used due to the danger of polluting the water supply with sludge. If the building is high enough a small tank fed over the top and controlled by a float valve may be used as a source of water. The height of the tank must be greater than the discharge head of pump or the sludge will be forced into the packing and probably result in the scoring of the shaft. If the tank cannot be set high enough, a small pump may be used to supply water to the seal. Grease seals and other special devices are sometimes used but are not as satisfactory as water seals.

Maximum Flow Gage for Sewers*

The accompanying sketch pictures the type of maximum flow gage, which has been installed in five manholes in the village of Shorewood in Milwaukee County, Wisconsin.

Metcalf and Eddy, in "American Sewerage Practice" (Vol. 1), under Maximum Flow Gages, describe a device that is substantially a stick with small vials attached along its length and inserted into a perforated pipe. The level of the mouth of the highest vial found full indicates the height to which the sewage has risen in the manhole. This design, however, has its disadvantages. First, the vials are breakable and entail considerable trouble in replacing. Second, it can not be used where the velocity exceeds eight feet per second.

The improvements in the Shorewood installation are:

First: It is cheap—the entire gage, made by a tinner and ready to install, costs very little.

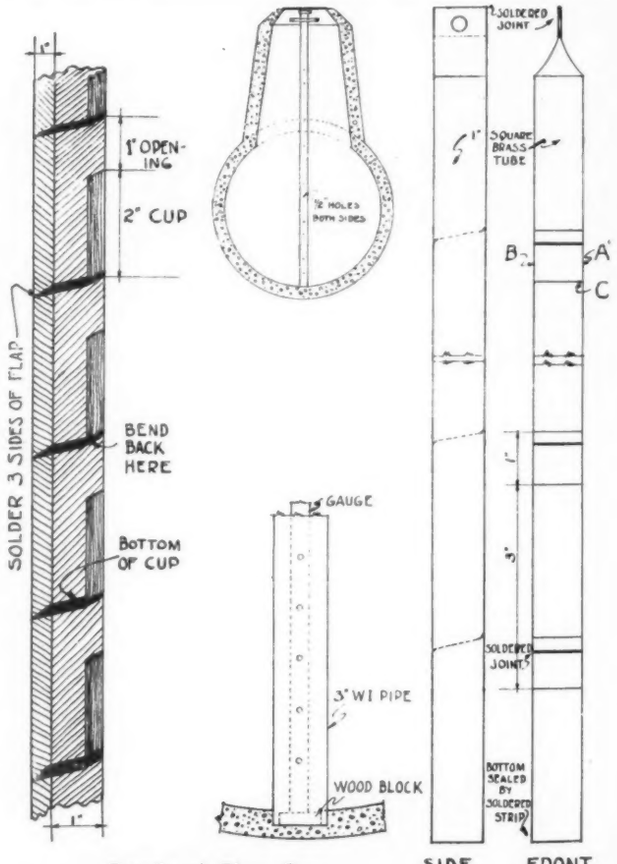
Second: It is not breakable and may be used in sewers regardless of velocity. Being made of brass or copper it is immune to corrosion.

A brief description may be helpful.—This gage is made of one inch (square) brass tubing, with one face (C on sketch) cut through at predetermined spacings. In the Shorewood design it is three inches. Then the corners are ground off on a power grinder to make edges A and B. The resulting flap is bent back and soldered in place to form the bottom of the pocket above. The block of wood is to raise the gage to the elevation of the invert of the sewer. The spacing of the pockets and the width of the mouths may be varied to suit circumstances. A perforated 2 in. W.I. pipe protects the gage.

In practice the gage has proven reliable and has served satisfactorily through several storms when the sewers were surcharged.

Credit for this design belongs to George Dewey Simms, Assistant Village Engineer, Shorewood, Wis.

*Contributed by Julius Lucoff, Milwaukee, Wis.



Details of Flow Gage

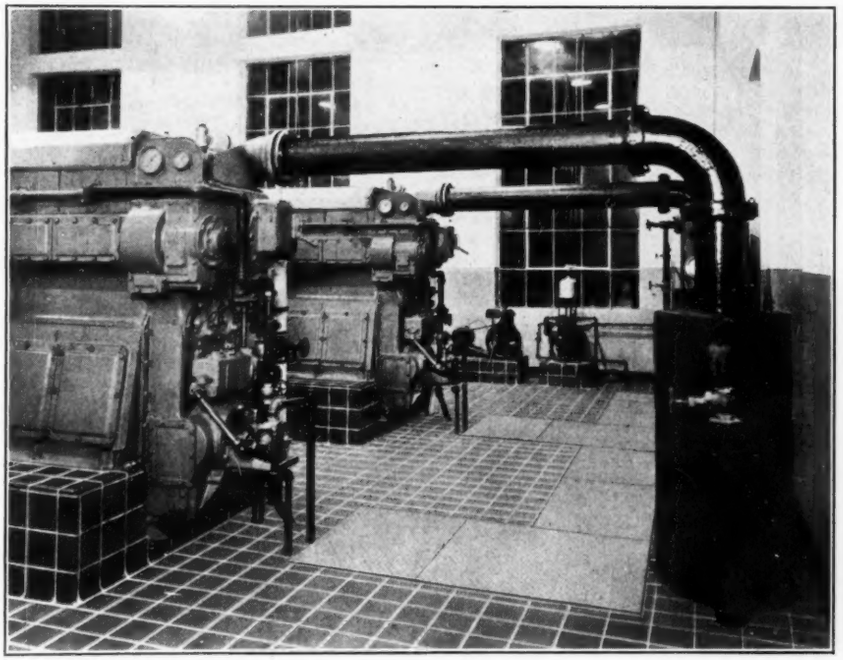
PRINCIPLES OF POWER GENERATION WITH SEWAGE-GAS ENGINES

By NORMAN C. WITTWER
Supervising Sanitary Engineer
Rahway Valley Joint Meeting
Rahway, N. J.

Many interesting accounts of sewage-gas engine power generating installations have been published in the engineering literature during the past several years. Several of these, particularly the articles of Walraven (1) and Sperry (2), in WATER WORKS & SEWERAGE and *Sewage Works Journal* have been outstanding in the technical thoroughness with which the authors discussed their experiences with this new and valuable adjunct to sewage treatment.

The writer has recently had occasion to make a comprehensive study of the feasibility of power generation with sewage-gas engines for the Sewage Treatment Works of the Rahway Valley Joint Meeting. The results of this study indicate that a very substantial saving in power costs is possible by the substitution of gas-engine generator sets for the present public utility power. Our current annual power bill is approximately $5,700.00, which covers cost of pumping all sewage entering the plant, power for all auxiliary pumps and mechanical equipment, and lighting.

It should be pointed out that the only justification for making a capital expenditure for power generating equipment to supplant outside power service must lie in the *net* annual savings in power costs which may be derived. The considerations for or against such an installation must be purely financial, as the self-generation of power will not add to, or detract from general sewage plant operation, or the results to be obtained from the treatment processes.



Twin 150 *H.P. Cooper-Bessemer Engine-Generator Sets for Durham, N. C. Note waste heat boilers on right.*

Arrangements Possible

Many arrangements are possible by reason of which the installation of sewage-gas engines may prove to be desirable. Some are as follows:

1. Engines direct-connected to sewage pumps where all or part of the plant flow is pumped.
2. Engines direct-connected to blowers used for aerating sewage.
3. Engines direct-connected to generators for generation of all or part of the electric power required.
4. Engines direct-connected to miscellaneous items of mechanical equipment.

This article will present the technical and economic phases of a complete power-generation plant designed to provide power for *all* the operating requirements of the Rahway Valley Sewage Treatment Works. While the Rahway Plant is a primary treatment plant having a capacity of 25 mgd, the type or size of plant does not in itself control the economics of sewage-gas power production. A number of factors influence the problem, and each should be thoroughly studied. They are as follows:

1. Experience at other sewage treatment plants where sewage gas power is being used.
2. Power requirements for the service desired—average and peak loadings.
3. Size and type of generating units required.
4. Standby power service.
5. Quantity and dependability of gas supply as compared to the average and peak power requirements.
6. Heat recovery for the heating of digestion tanks and buildings.
7. Probable first cost.
8. Annual interest and amortization charges.
9. Operating and maintenance costs.
10. Annual savings, if any, as compared to the present power costs.

Experience at Other Sewage Treatment Plants

It was first thought advisable to investigate the experience at other sewage treatment plants where gas engines are in use. Accordingly, questionnaires were sent to a number of sewage treatment plants which have been using sewage-gas power over varying periods of time. The information obtained from these questionnaires is tabulated in Table 1, and may be summarized as follows:

1. Three plants from which replies were received were larger than our plant, ten were smaller.
2. All showed a net annual savings. Some indicated that interest and depreciation were first charged off; the others did not clearly stipulate.
3. The annual cost of repairs as compared to power production in most cases is very low.
4. The annual cost of lubricating oil in most cases is very low.
5. In most cases, a statement was made to the effect that the engines were operated by the regular force, with no additional men.
6. Each reply indicated that sewage-gas generation of power is satisfactory and practical.

Power Requirements

The power requirements for a new plant must be estimated, but for a plant in operation with a back-log of operating records,

the present and probable future requirements can be determined with a fair degree of accuracy.

By an examination of the first three columns of Table 2 under the heading "Hourly Rates of Power Consumption," it can be seen that the hourly power demand during an average day for the Rahway Valley Plant approximated 40 KWH during the first ten months of 1938. The hourly average of a maximum day during this period was 114 KWH, while for a minimum day it was 23 KWH. Temporary demands higher than 114 KWH have been recorded on the local power company's demand chart, the highest being 124 KWH during a heavy storm in September. Such extreme peak demands, although not frequent, do occur occasionally.

From these records, the folowing power requirements were determined:

Average	40 KWH
Moderate Peak	99 KWH
Extreme Peak	124 KWH

A generating plant to take care of the above loadings will be as follows:

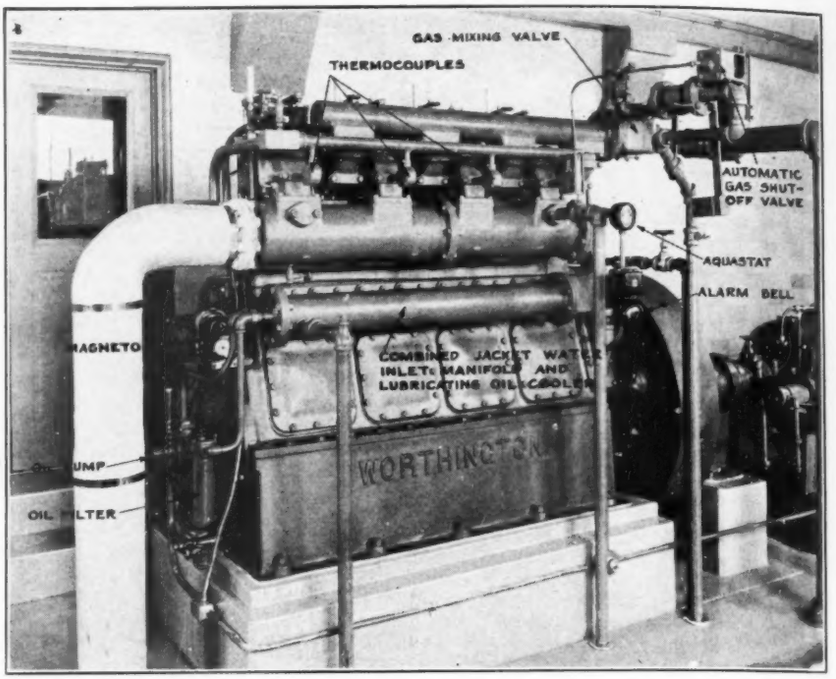
One 60 KW generator set to provide power for average demands, with sufficient reserve power for minor fluctuations.

One 60 KW generator set to serve as alternate to the first set, and to provide the additional power required for the peak demands.

Note:—Both generators operating in parallel will generate 120 KWH, and will easily stand the temporary overloading required to produce 125 KWH.

Some form of standby power service is always desirable. If the charges are within reason, an outside power company connection is the most practical. If such charges are too high, and they usually are, an arrangement may be made to use the local gas company's gas in case the supply of sewage gas fails. The scheme has proved entirely feasible and economical at existing plants.

If gasoline is to be used, a carburetor should be provided on the engine by means of which the engine may be operated as a gasoline engine. In the case of the Rahway Valley Plant, it is intended to cut off the local power company entirely and to use gasoline as the auxiliary fuel to serve as a standby.



Worthington 120 H.P. Engine at Ann Arbor, Mich. Direct Connected to Blower

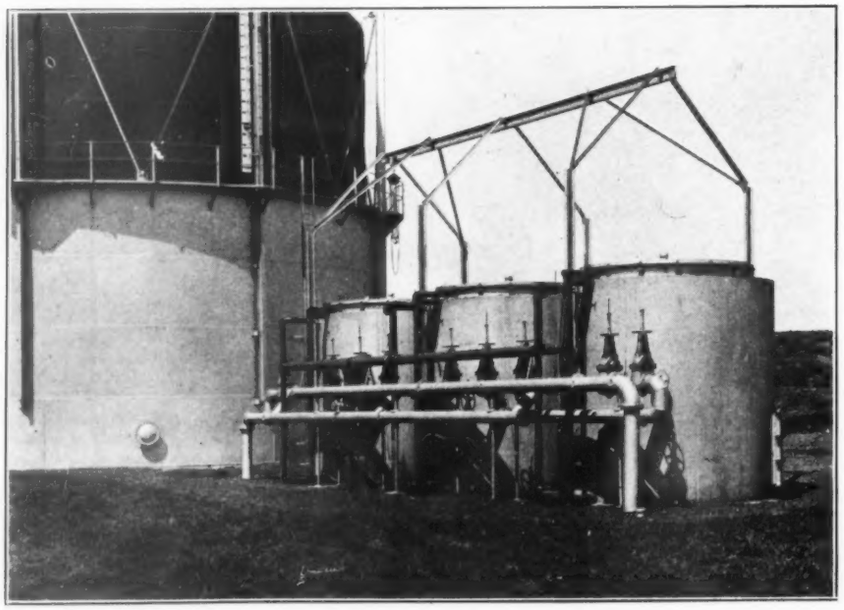
Selection of the Engine

The More Important Considerations

Many gas engines are on the market, some of which have been especially adapted to the use of digester gas as a fuel. The most serviceable type is the heavy-duty, slow-speed engine. Such engines are built to run continuously for a number of years with low cost of repairs and maintenance, and embody the standards of construction and the principal features of the heavy-duty Diesel engine.

Some sewage treatment plants have installed the lighter-weight, higher-speed automotive type of gas engine which is less expensive in first cost. However, experience has proven that in general these engines cannot be subjected to continuous service over protracted periods of time without high maintenance costs. In addition, their total useful life is much shorter than that of the heavy-duty engine, so that in the long run, the heavy-duty engine may be expected to prove the more economical type.

The special features to be considered in choice of engines are those involving long life and low maintenance costs. Valve-in-head engines are preferable in the smaller sizes. In the larger sizes, valves should be in removable cages, or should be otherwise easily removable for convenience in inspection and grinding of valves. Renewable valve-seat inserts should be provided for the exhaust valves, preferably of some high grade heat resisting metal such as "Stellite."



Koppers Gas Purifiers and Gas Holder at Peoria, Ill.

An engine of unit-block frame type, bolted direct to the engine base, is preferred. Each cylinder head should be a separate casting, and renewable cylinder liners of a high strength material should be provided so that wear in a cylinder will require the replacement of a liner only, rather than a complete cylinder. It was found at the Coney Island (N. Y.) Plant that the liners can stand three reborings before replacement is necessary.

The main bearings should be lined with a high-grade anti-friction metal, and should be fitted so that they can be removed without disturbing the crankshaft. Easy access should also be provided to the connecting-rod bearings. Water jacket space should be accessible for cleaning through ample covered openings inside of the frame.

When the engine is direct-connected to a generator, a fly wheel should be mounted on the drive end of the crank shaft. It should be dynamically balanced and have sufficient inertia to insure the degree of uniform rotation required for generator operation. A governor should be provided which will satis-

factorily control the speed of the engine to the limits required for the guaranteed operation of the generator.

The customary oil filter and air filter should also form a part of the installation. Safety devices are also very desirable, such as an electric alarm and automatic shutdown system, to protect the engine against low lubricating oil pressure and excessive jacket water temperature.

The desirable features *not* customarily found on automotive types of engines may be summarized as follows:

1. Unit-block frame bolted direct to engine base.
2. Cylinder heads as separate castings.
3. Renewable cylinder liners.
4. Renewable valve-seat inserts for exhaust valves.
5. Valves readily removable.
6. Main bearings mounted in engine base.
7. Main bearings readily removable.
8. Water jacket space accessible for cleaning.
9. Flywheel, if engine drives a generator.
10. Governor to control engine speed.
11. Safety devices.
12. Piston speed not to exceed 1000 feet per minutes.
13. Brake mean effective pressure not to exceed 70 pounds per square inch.

Quantity, Quality and Dependability of Sludge Gas

The evolution and production of sewage gas is normally a continuous and uninterrupted process, resulting from the biological decomposition of sewage sludge in digestion tanks. During this process a portion of the volatile organic matter in the sludge is converted into a combustible gaseous mixture which is approximately

Methane	64%
Carbon Dioxide	30%
Nitrogen	5%
Hydrogen Sulphide	Trace
Other Gases	1%

Weekly analyses of the gas at Rahway have been run since the plant was placed under operation. From these analyses (made with a Bureau of Mines Gas Analysis Apparatus) the average heat value of the gas has been found to be about 650 Btu. per cubic foot. This is slightly higher than commercial gas, which runs about 550 Btu. per cubic foot. In an internal combustion engine, about 10% of this heat is not available, this being the heat of vaporization. Thus the dependable minimum heat value of the gas becomes 575 to 600 Btu. per cubic foot.

Importance of Gas Storage

Table 2 indicates that a uniform and dependable supply of gas is available at our plant at all times. The average daily gas production for January to October was 71,000 cubic feet. However, since individual days have shown productions as low as 60,000 cubic feet, it has been assumed for the purpose of this study that at all times 60,000 cubic feet of gas will be available as the dependable minimum per 24 hours for power generation purposes. The assumption is doubly conservative due to the fact that we have a reserve gas supply of approximately 45,000 cubic feet in storage under 6 inches water pressure. This reserve supply is held in our secondary digestion tanks, the upper portion of which are in reality single-lift gas holders. It becomes apparent that one of the prime requisites of a practical and successful sewage-gas engine installation is a gas holder having ample storage capacity to carry over during periods of lower-than-average gas production.

Hydrogen Sulphide and Its Removal

The presence of hydrogen sulphide (H_2S) in objectionable quantities in digester gas may prove injurious to the pistons and cylinder walls of gas engines. While hydrogen sulphide itself is not seriously corrosive, its products of combustion, water and sulphur dioxide (SO_2) unite to form the highly corrosive sulphurous acid (H_2SO_3). The same products of combustion result from the presence in the gas of any form of sulphur; therefore, any volatile sulphide is just as objectionable in an engine fuel as is hydrogen sulphide.

Where the sulphide content of a sewage gas exceeds 0.07 percent by volume, or approximately 50 grains per 100 cubic feet, scrubbers should be used to clean the gas before it enters the engine. Sulphur as hydrogen sulphide may be removed by passing the gas through a bed of finely divided iron oxide and wood shavings. The iron oxide reacts with the hydrogen sulphide to form sulphide of iron and water, according to the following equation.

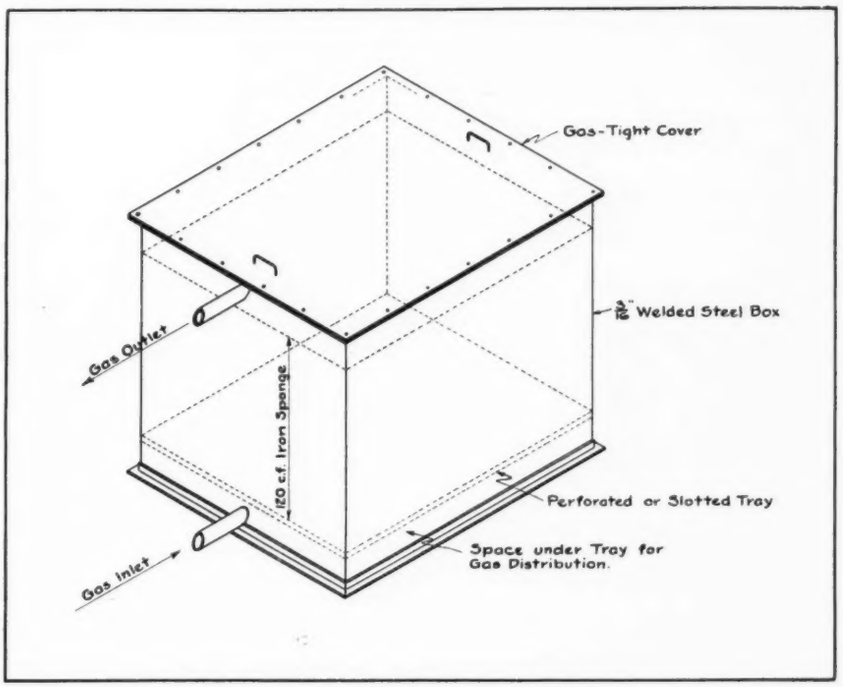
$$Fe_2O_3 + 3H_2S = Fe_2S_3 + 3H_2O$$

The wood shavings merely serve to keep the mass of iron oxide open, forming an "iron sponge," so that the gas can pass through without too much resistance.

At most sewage treatment plants, little or no trouble has been experienced due to hydrogen sulphide in the gas. Some plants, however, have found it necessary to first remove the sulphur. Several of these have installed a commercial type of scrubber, among them the plants at Peoria, Illinois, Fort Atkinson, Wisconsin, and Battle Creek, Michigan.

An inexpensive, home-made gas scrubber can be constructed by following the design used at Galesburg, Illinois (3), as here sketched. It consists of a rectangular box providing a convenient depth of "iron-sponge" and a perforated or slotted tray which carries the sponge. The tray is supported about three inches above the bottom of the box to permit the gas to be distributed over the entire area before passing upward through the sponge.

Since the chemical action between hydrogen sulphide and the iron oxide takes place more readily at temperatures above 60° F., the box should either be located in a warm place, or insulated,



Home-Built Sulphide Scrubber at Galesburg, Ill.

or provided with heating coils. (The Peoria scrubbers here pictured are provided with artificial heat.) The inside of the box should be well coated with an asphaltic paint to prevent corrosion.

The calculations for a gas scrubber for 80,000 c.f.d. of gas containing 100 grains H_2S per 100 cubic feet are as follows:

1. Sufficient "iron sponge" should be provided to last about 60 days.
2. 1 cu. ft. of sponge contains about 20 lbs. of ferric iron.
3. 20 lbs. of ferric iron will theoretically react with 127,000 grains of H_2S.
4. Practical considerations cut this figure to about one-third, or 40,000 grains of H_2S.
5. Average H_2S content in the gas under question is 100 grains per 100 cu. ft.
6. Total H_2S in 60 days = 100 x 800 x 60 = 4,800,000 grains.

7. Total quantity of "iron sponge" required is

$$\frac{4{,}800{,}000}{40{,}000} = 120 \text{ cu. ft.}$$

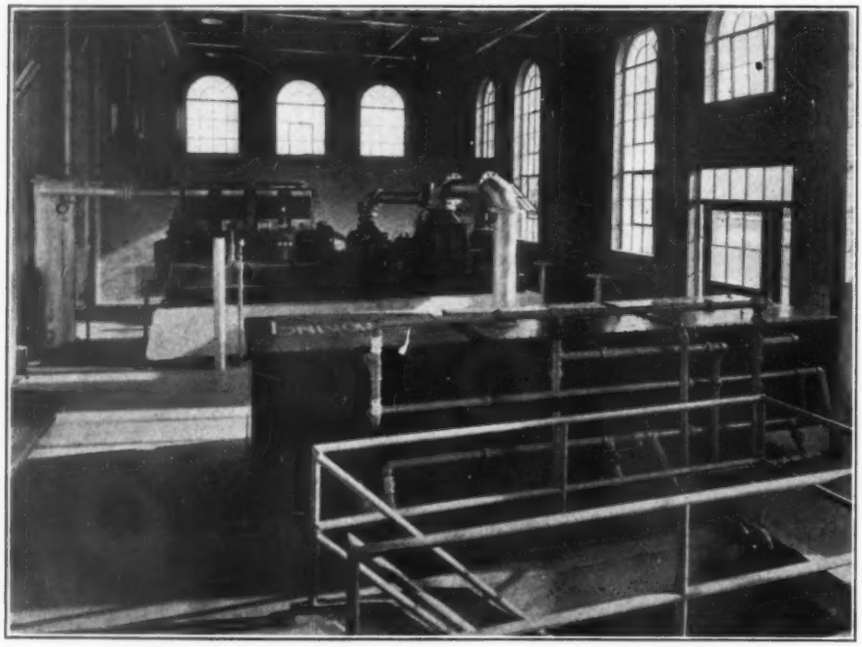
The useful life of the sponge may be extended by regeneration. If the exhausted (sulphided) sponge is *carefully* exposed to the air, the iron sulphide will absorb oxygen, enabling the iron to revert back to its original ferric oxide condition as follows:—

$$2Fe_2S_3 + 3O_2 = 2Fe_2O_3 + 6S$$

This reaction generates so much heat that the sponge may take fire and be ruined. However, rate of regeneration may be controlled by wetting the old sponge thoroughly with water, and then removing it from the box to a pile in the open air. When it has changed from a black to a dark brown color, it is again ready for use. "Iron Sponge," thus regenerated, may be used two to three times before finally discarding.

When charging the box with sponge, care must be taken to pack uniformly. It should be lightly tamped several times while filling. Careful tamping around the sides of the box will prevent leakage of gas.

An accompanying picture shows three home-built scrubbers at Chicago Heights, Ill.



Three Home-Built Gas Scrubbers at Chicago Heights, Ill.
Beyond is 125 H.P. Climax engine direct connected to 2500-cu. ft. Pottstown blower.

Engine Gas Supply

Most engine manufacturers will guarantee the fuel consumption at full load to be not in excess of 10,000 Btu. per BHPH. This is equivalent to 15,000 Btu. per KWH. For a sewage gas having a low heat value of 575 Btu. per cubic foot, the consumption will be

$$\frac{15{,}000}{575} = 26.1 \text{ cu. ft./KWH}$$

At other loadings, the fuel requirements will be approximately as follows:—

1/2 Load—32.7 cu. ft./KWH
2/3 Load—29.3 cu. ft./KWH
5/6 Load—27.5 cu. ft./KWH

The total daily engine gas consumption shown in Table 3 was computed on the basis of using one engine up to 60 KW demand, and above 60 KW demand using both engines in parallel, each taking one-half the total load.

The sewage gas is introduced into the engine through a gas mixing-valve which mixes the gas with atmospheric air in the proper proportions. The function of this valve is similar to that of a carburetor on a gasoline engine. It should contain an air valve and a gas valve, each separately regulated in order that the fuel mixture may be changed to suit the varying Btu. content of the sewage gas.

The gas pressure ahead of the mixing valve should be reduced by means of a suitable pressure regulator to atmospheric pressure. To insure a constant supply of gas at atmospheric pressure at all times, a gas reservoir is usually installed between the mixing valve and the pressure regulator. The size of this reservoir depends upon the engine rating, but should not be less than about 30 cubic inches per horsepower.

Heat Recovery

(a) From Jacket Water

In most cases where sewage gas is being used for power, part or all of the waste heat from the engine is recovered for the heating of digestion tanks and buildings. If this were not done, the heat normally derived from the gas would have to be replaced by other fuels, such as coal or oil. Such an arrangement would probably prove economically unsound. Therefore, if gas is used for power purposes, no additional heating cost should be incurred, and such heat as may be required should be obtained from the engine waste heat, and from the excess gas.

The heat consumed in a gas engine, the heat wasted, and the heat which is recoverable depend upon the type of engine. For a 90 HP., four-cycle, slow-speed engine operating under full load, a typical heat balance is as follows:—

Heat going to useful work.....25.5%
Heat to radiation.....3.5%
Heat to jacket cooling water.....35.5%
Heat to exhaust and friction.....37.5%

Of the above heat, all of that carried away by the jacket cooling water can be recovered by connecting the jacket water piping into the hot water heating system. For best operating conditions, the cooling water should enter the engine at between 110° F. to 130° F., and should leave the engine at between 140° F. to 160° F. Approximately 3300 Btu./-BHPH must be removed from the engine jacket water to insure efficient cooling. Therefore, if the engine jacket water is passed through the digestion tank heating coils, these coils, acting as a water cooler, must be able to extract this amount of heat from the jacket water both winter and summer. If not, all or part of the jacket water must be circulated through a separate water cooler.

For a 90 HP engine operating at full load the heat recoverable from the jacket water is therefore

$$3300 \times 90 = 297{,}000 \text{ Btu/hr.}$$

The amount of a jacket cooling water required for a 30° F. temperature rise will be

$$Q = \frac{3300 \times 90}{30\ (^\circ \text{ Temp. diff.}) \times 8.34} = 1190 \text{ gph.}$$

In the jacket water system, therefore, we must provide a cooler (digestion tank or other) to extract the necessary heat from the water. We have calculated that a circulating water pump of at least 20 gpm (1190 gph) capacity will be required to ensure positive water circulation. A vented surge tank should be installed at the high point of the jacket water system, either between the engine outlet and the cooler, or just ahead of the circulating pump. Thermometers should be provided at the cold water inlet and the hot water outlet.

(b) From Exhaust Gas

A portion of the heat normally carried away by the exhaust gases is recoverable. The quantity recovered is governed by practical limitations in the size of the waste heat boiler, and also by the lower temperature limit to which gases can be safely cooled without condensation and the consequent corrosion of the surfaces with which they come in contact.

The importance of avoiding condensation of the moisture contained in the exhaust gases cannot be too highly stressed. The point of condensation, often called the dew point, has been found to be about 130° F. However, an exhaust gas temperature slightly higher than 130° F. is not sufficient to avoid condensation, due to the fact that exhaust gas temperatures drop very sharply when

they come in contact with surfaces having a water temperature below 130° F.

This sudden temperature drop is due to the inability of the gas film adjacent to the heating surface to transmit the heat from the main body of the gases to the water quickly enough. The resistance offered by the gas film causes the moisture in the gases to condense on the cold surfaces even though the main body of gases are at temperatures far above the dew point. Hence it is obvious that the water inlet temperature should not be less than 130° F., and the lower temperature limit of the main body of the exhaust gas should be well above the dew point. Experience has indicated that 300° F. is a safe minimum exhaust gas temperature.

Where 130° F. water is not available, the ideal method of reclaiming waste heat is by means of a waste heat boiler generating low pressure steam. The steam generated therein is delivered to an independent tubular heater through which water passes in the tubes. When the steam condenses in the independent heater, the condensate returns by gravity to the waste heat boiler where it is again evaporated. In this manner the cycle is closed and the water temperature remains well above 130° F., except for short periods when starting up after long shut downs. Nevertheless, practically all condensation with its consequent corrosion is eliminated.

At Rahway we have decided upon a waste heat boiler which will extract sufficient heat to cool the gas from 900° F. to 300° F. at full load. Obviously, at fractional loads, the final gas temperature will be under 300° F. due to the lower initial temperature and smaller gas quantities, but at low loads it will still be above the dew point. As a further precaution against corrosion, the cooling water will first be circulated through the engine jackets as the cooling medium for the engines. In so doing, the water will be preheated from 110° F. to 140° F. before entering the waste heat boiler. This double precaution against the possibility of a highly corrosive condensate appears to be the best guarantee for the long life of the equipment, and for low maintenance costs.

A waste heat boiler (see first cut) is a shel land tube type of boiler, the exhaust gases being passed through the boiler tubes, and the heat being absorbed by the cooling water which completely fills the shell and surrounds the tubes. The exhaust gases, cooled down considerably by the boiler, pass on out to atmosphere. The waste heat boiler itself will also serve as a silencer, no further silencing being necessary. Where a by-pass around the boiler is provided, a suitable silencer should be installed on the by-pass line. The arrangement proposed at Rahway will make it possible to by-pass all or a part of the exhaust gases around the boiler by means of a 3-way regulating valve. The piping is also so arranged that the jacket water can be by-passed around the waste heat boiler.

A pyrometer will be provided with a sufficient number of themocouple selection points to permit temperature readings of the exhaust gas to be taken at each cylinder, and at the discharge from the waste heat boiler.

Naturally, the amount of heat going into the exhaust gas depends upon the bore and stroke, number of cylinders, speed and type of engine. A four-cycle engine with water-cooled exhaust manifold will produce exhaust gases having temperatures of from 800° F. to 900° F., while the exhaust gases from a two-cycle engine will probably range from 300° F. to 500° F.

A typical range of exhaust gas quantities and the corresponding temperatures for a 90 H.P., four-cycle engine operating under several loadings is shown below. This data must be obtained from the manufacturer of the engine to be used.

	Exhaust Gas Quantity	Temperature
1/2 Load	683 Lbs./hr.	850
2/3 Load	845 Lbs./hr.	866
3/4 Load	918 Lbs./hr.	875
5/6 Load	994 Lbs./hr.	883
Full Load	1130 Lbs./hr.	900

Obviously, the quantity of heat which may be extracted from the exhaust gas depends upon the difference between the initial and final temperatures, and the specific heat of the gas. The specific heat of the exhaust gas from a gas engine will be about 0.24, this representing the ratio of the heat required to raise one pound of the gas 1° F., to the heat required to raise one pound of water 1° F. Therefore, the heat recoverable from the exhaust gas of a 90 HP., four-cycle engine operating under full load will be

$$1130 \text{ lbs./hr.} \times (900° - 300°) \times 0.24 = 162{,}720 \text{ btu/hr.}$$

(c) From Engine Radiation

The heat radiated from the engines (about 3.5%) cannot be transferred to the hot water heating system, but it does assist in the heating problem by partially heating the engine-room, thus relieving the heating system of this portion of the total heating load. Generally speaking, the radiation losses at the engine will be from 2 percent to 4 percent of the total heat input.

Heat from Excess Gas

At Rahway we have at present a hot water heating plant which heats the digestion tanks and all buildings. The boilers are operated exclusively on sewage gas. The Heat Exchange Diagram on the next page shows how the heated water from the engine-room will be run directly into the return line at the bottom of the boilers, and circulated through the boilers where the temperature will be raised to the desired degree. The return water to the engines will be taken from the digestion tank return water, which averages about 110° F. In using the boilers to "jack-up" the temperature of the heating water, we must rely on the sewage gas which may be left over after all engine requirements have been satisfied. Since the boiler efficiency approximates 68 percent, the boiler heat output which is available when one engine is operating under a 60 KW demand will be

$$\frac{22{,}500 \times 650 \times 0.68}{24} = 415{,}000 \text{ btu/hr.}$$

This is shown in Table 3.

Thus it is apparent that the system will be extremely simple and yet highly flexible. The combined heat from the exhaust gases and the jacket cooling water can be used to heat the digestion tanks in summer, and to aid in the heating of tanks and buildings in the winter. Exhaust gas heat can be recovered, or it can be by-passed as desired. Since our average power load is 40 KW, it can be seen that sufficient heat is available to meet all normal winter heating requirements.

Construction and Operating Costs

Estimate of Cost

Two 90 HP.—60KW—100 KVA heavy duty gas-engine generator sets complete with gauge boards, gas reservoirs, Maxim silencers, exhaust gas pyrometers, electric alarm and shutdown systems, water circulating pumps, starting air equipment, gasoline carburetors, and installation	$19,000.00
Two Waste Heat Boilers	660.00
Two 3-Way Regulating Valves	240.00
Generator panels, with ammeters, voltmeters, wattmeters, frequency meters, voltage regulators, field rheostats, Synchroscope	2,340.00
Distribution Panel, Electric Wiring and Lighting	1,600.00
Station Piping	1,000.00
Outside Piping	3.500.00
Building (29′ x 39′ x 15′)	6,000.00
1½ Ton Crane and Hoist	450.00
Engine Foundation (3 Engines)	800.00
Gas Meter	400.00
Contingencies	1,200.00
Total Estimated Construction Cost	$37,190.00
Legal, Administrative, etc.	3,000.00
Total Estimated Cost	$40,190.00

Amortization and Operating Costs

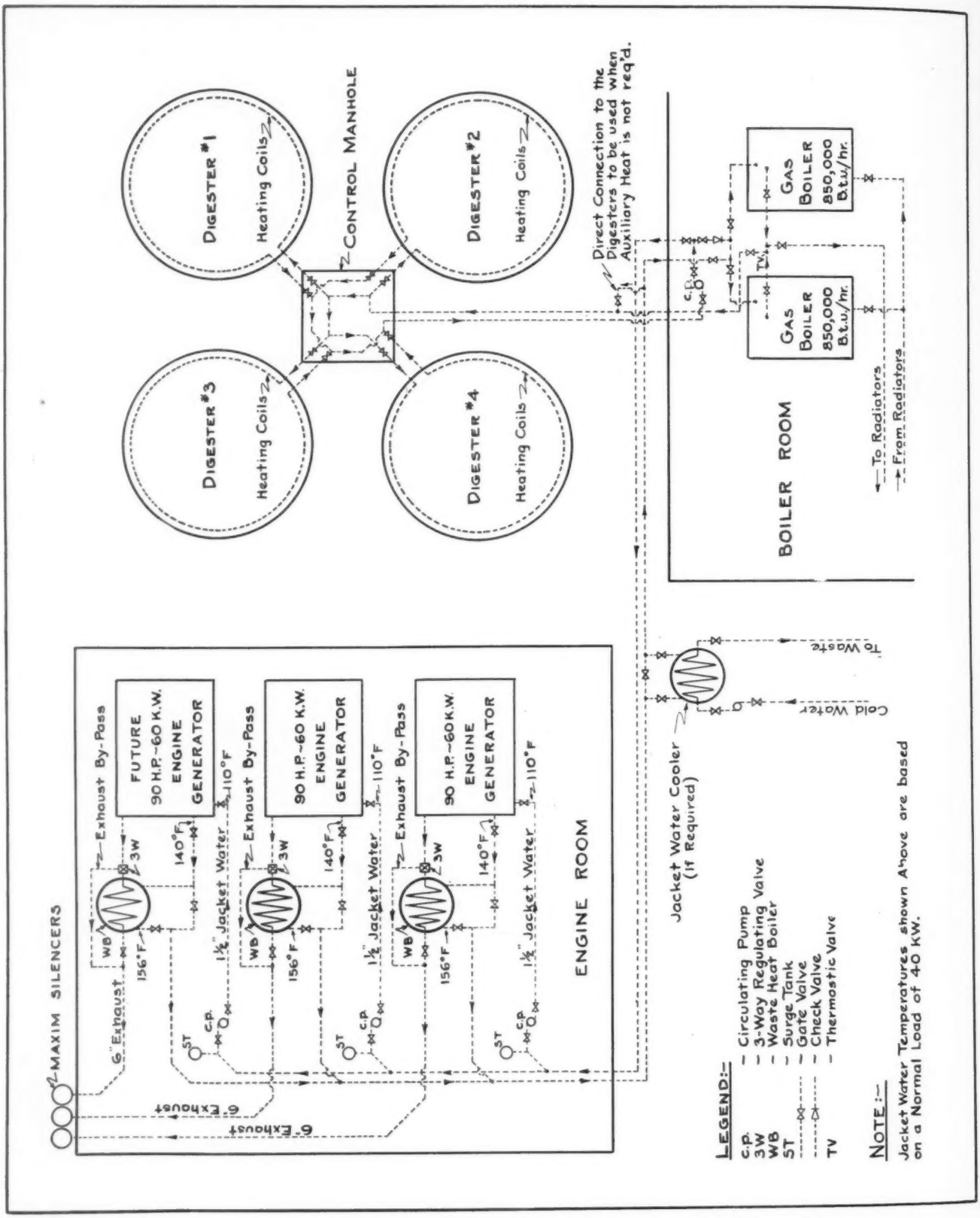
Gas engines, when on continuous service, are generally conceded to have a useful life of from 15 to 20 years. With two engines, each capable of carrying the normal load, the service is divided. Hence, the life of each engine may be conservatively set at 20 years.

By looking back at Table 1, it will be seen that in most cases the cost of additional labor to operate and maintain the engines is negligible. In fact, a number of the replies indicated that no additional labor cost was incurred.

Experience on the cost of repairs and lubricating oil seems to differ widely. A fair allowance for repairs is $2.00 per BHP per annum. This figure is somewhat higher than the engine manu-

facturers themselves predict on the basis of their own experience, and is thus felt to be sufficiently conservative for the purpose of this analysis.

Lubricating oil at most plants amounts to about 1 gallon for 2000 BHPH. However, oil consumption can be reduced somewhat by the use of oil refiners. At the Rahway plant, we estimate a total of 335,000 KWH per annum, which is equivalent to 500,000 BHPH. Our oil consumption, therefore, is expected to be approximately 250 gal.



Heat Exchange Diagrams Developed for the Rahway Valley Plant

Annual Charges and Savings

Interest on Investment @ 4%	$1,607.60
Amortization of Engine— 1/20 x $21,300	1,065.00
Amortization of Miscellaneous Equipment— 1/25 x $6,400	256.00
Amortization of Permanent Structures and Piping— 1/30 x $12,490	416.33
Repairs—57 BHPH/annum @ $2.00	114.00
Lubricating Oil—250 gallons @ 12c	30.00
Estimated Annual Cost	$3,488.93
Present Annual Power Cost*	5,700.00
Net Annual Saving (based on present power cost)	$2,211.07

*Our purchased power cost will increase from year to year as the sewage load increases, hence the savings will likewise increase.

References

(1) W. B. Walraven "Development of Power from Sewage Sludge Gas," Sewage Works Journal, Vol. 4, Page 614 (July, 1932). "Experience with Gas Engine Operation—During Three and One-Half Years of Use," Water Works & Sewerage, p. 370, Vol. 83 (October, 1936). Water Works & Sewerage, p. 151, Vol. 80 (May, 1933).

(2) W. A. Sperry "Gas Engine Installation—Aurora, Illinois," Water Works & Sewerage, Page 11, Vol. 84 (January, 1937) and Page 327, Vol. 84 (September, 1937).

(3) L. W. Hunt, Chief Chemist, the Galesburg Sanitary District—by letter.

TABLE 1. TABULATION OF DATA ON POWER GENERATION FROM SEWAGE GAS

(Taken from replies to questionnaire)

Location	Pop. Served	Total H.P.	Make of Engine	Gas Production c.f.d.	Gas Consumption cu. ft.	Net Annual Savings	Annual Repairs	Annual Lubric. Oil	Additional Annual Labor Cost
Battle Creek, Mich.	36,300	60	Le Roi	59,000	8/BHPH	$2,004	$ 55	$ 90	None
Los Angeles, Cal.	374,000	450	Clark	250,000	24/BHPH	4,600	100	325	None
Green Bay, Wisc.	40,000	210	Worthington	40,000	26/KWH	2,835	96	189	$234
Cedar Rapids, Iowa	55,000	200	Worthington	147,760	15/BHPH	6,000	300	700	275
Janesville, Wisc.	20,000	30	Worthington	25,000	17/BHPH	850	600	110	150
Grand Rapids, Mich.	178,000	150	Buda	138,000	——	1,000	15	30	30
Fort Atkinson, Wisc.	6,000	15KVA	Le Roi	75,000	24/Kwh	1,950	300	75	None
Richmond, Ind.	28,000	120	Worthington	25,000	9.5/BHPH	6,000	None	200	None
Ann Arbor, Mich.	40,000	120	Worthington	50,000	15/BHPH	6,000	None	170	None
Topeka, Kans.	50,000	360	Worthington	Ample	——	5,400	200	425	——
Aurora, Ill.	49,000	140	Climax	49,500	21.8/BHPH	*	219	88	None
Kokomo, Ind.	36,000	45	Worthington	15,000	19/BHPH	1,800	None	55	None
Toledo, Ohio	60,000	535	Rathbun	250,000	9500Btu/ BHPH	13,299	382	576	None

*Plant operating cost reduced 20%.

TABLE 2. GENERAL DATA ON POWER, GAS PFODUCTION, AND HEAT REQUIREMENTS

(As determined for the Rahway Valley Plant)

Month	Hourly Rates of Power Consumption			Max. Demand from Demand Chart KW	Gas Production		Heat Requirements				
							Digestion Tanks				
	Max. Day KWH	Min. Day KWH	Monthly Aver. KWH		Average c.f.d.	Maximum c.f.d.	Aver. Circ. Water g.p.h.	Temp. Diff. °F	Heat Req'd Btu/hr.	Heating of Buildings	Total Heat Required Btu/hr.
January	80	23	35	99	63,000	85,000	3,600	18	540,000	400,000	940,000
February	57	30	39	70	68,000	86,000	3,500	17	485,000	400,000	885,000
March	73	33	42	78	67,000	86,000	3,620	21	635,000	350,000	985,000
April	60	30	39	76	72,000	89,000	3,500	23	670,000	200,000	870,000
May	37	27	31	50	61,000	79,000	3,250	19	516,000	75,000	591,000
June	60	23	32	51	73,000	87,000	2,780	23	535,000	0	535,000
July	113*	27	43	119*	72,000	85,000	3,480	13	377,000	0	377,000
August	40	27	35	72	70,000	81,000	3,400	16	453,000	0	453,000
September	114*	27	39	124*	85,000	104,000	3,100	15	387,000	0	387,000
October	40	27	37	60	78,000	103,000	3,250	17	462,000	80,000	542,000
Average					71,000						

*Exceptionally Heavy Storms.

TABLE 3. FUEL AND HEAT BALANCE

Daily Load	Engine Gas Consumption		Excess Gas*	Boiler Heat Available from Excess Gas**	Recoverable Heat		Radiation from Engines		Total Heat Available	Aver. Heat Req'd during Winter Months	Max. Heat Req'd for a Zero Day
					From Jacket Water	From Engine Exhaust	% Loss	Heat			
KWH	Btu/KWH	c.f.d.	c.f.d.	Btu/hr.	Btu/hr.	Btu/hr.		Btu/hr.	Btu/hr.	Btu/hr.	Btu/hr.
80	16,800	56,000	4,000	74,000	396,000	238,000	2¼	30,000	738,000	850,000	1,070,000
70	17,600	51,200	8,800	162,000	345,000	216,000	2½	34,000	757,000	850,000	1,070,000
60	15,000	37,500	22,500	415,000	297,000	163,000	1½	15,000	890,000	850,000	1,070,000
50	15,800	33,000	27,000	495,000	248,000	138,000	2	17,000	898,000	850,000	1,070,000
40	16,800	28,000	32,000	590,000	197,000	119,000	2¼	16,000	922,000	850,000	1,070,000
30	18,800	24,000	36,000	660,000	149,000	95,000	2½	16,000	920,000	850,000	1,070,000

*Daily Average Gas Production to be expected is 60,000 c.f.d.
**Hot Water Boiler Efficiency estimated at 68%.

NOTES:
High heat value of sewage-gas = 650 Btu; low heat value = 575 Btu.

Fuel requirements and heat recovery, based on the following:
Engine—Worthington 90 H.P.—60 K.W. Type BG-3.
Waste Heat Boiler—Davis Paracoil N-70.

PACIFIC FLUSH-TANK COMPANY

Designers and Manufacturers of Sewerage and Sewage Treatment Equipment
Exclusively Since 1893

New York **4243 Ravenswood Ave., Chicago** **Charlotte, N. C.**

From the largest city in the country to the smallest, P.F.T. Equipment with its inherent efficiency and sound construction that results from over 43 years of experience, field study and research, is providing dependable daily operation. P.F.T. is the largest exclusive builder of sewage treatment equipment.

Representative units in the P.F.T. Line are shown below.

1. P.F.T. Floating Cover Digesters serve hundreds of cities today. They effectively control and accelerate digestion, eliminate odors, salvage gas for use in power and heating. For two stage or single operation. Built in a variety of shapes and sizes for every requirement. A few of the 87′ units at Denver, Colo., are shown. Described completely in P.F.T. Catalog 132.

2. Rotary Distributors are built from single units 50′ or smaller in diameter to multiple installations 120′ or more each in diameter. They provide thorough distribution and feature P.F.T. Patented Hinged Spreader Jets, long lasting bearings and a positive mercury seal. A few of the 25 units, 165′ each, at Dayton, Ohio, are shown. Send for Bulletin 113.

3. "Double-Flow" Rotary Distributors were designed to provide a maximum range of flow under a minimum differential of head. Two arms operate at low flows with the other two arms coming into service when the rate of flow increases to a predetermined volume. A lower head is thereby required to discharge a given volume of sewage. The unit is automatic, using "humps" to control flow. Pumping costs are eliminated and the need for dosing tanks and other controls is greatly reduced. One of various distributors developed by P.F.T.

4. P.F.T. Sprinkling Filters available with several types of spray nozzles. A large P.F.T. installation at Akron, Ohio, one of many, is shown.

5. P.F.T. Waste Gas Burners are ruggedly constructed for safe, dependable service, have a series of fire brick baffles, vented combustion chamber with pilot that is adjusted from outside. Ask for Bulletin 121.

6. P.F.T. Type "B" Pressure Relief Waste Gas Flame Traps eliminate explosion hazards from digestion tank gases. Give complete protection without use of water seals at the same time reducing to a minimum gas pressure loss. Detailed in Bulletin 121.

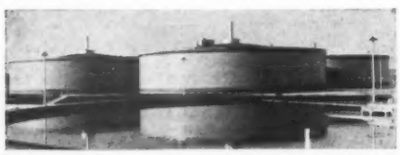
7. P.F.T. Condensate Drip Trap safely, effectively removes small quantities of moisture from gas lines without danger of gas leakage. Installed at lowest point in line so moisture can drain to it for periodical draw-off. Turning handle 180° positively closes gas line before drain is opened. Operates at pressures to 1 lb. per sq. in. Holds about 2 qts. of entrained liquid.

8. P.F.T. Sludge Pumps are made with large, clean, non-clogging passage-ways in various sizes for stationary and portable use. Single, double and triple plunger types with adjustable eccentrics to regulate capacity. Anti-friction bearings, special rubber ball valves. Over 500 in use. Send for Bulletins 40-A and 50.

9. P.F.T. Alternating Siphons serve thousands of sand filter bed installations. Built for years of efficient service. Bulletin 124 gives details.

10. P.F.T. Twin Tank Controls for dependable dosing of sprinkling filter beds. Typical P.F.T. engineered design. Hundreds of successful installations. Write for Bulletin No. 30.

11. P.F.T. Tray Clarifiers provide rapid precipitation of solids through a series of shallow settling areas over which sewage is spread with minimized turbulence. Sludge blanket on each tray facilitates more thorough removal of colloidal particles. Details covered by Bulletin 110.



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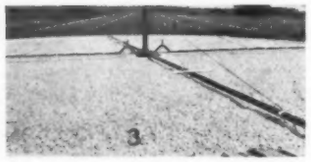
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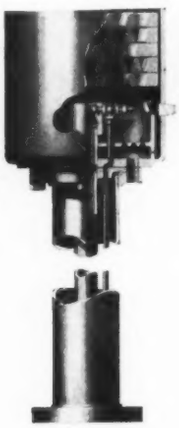
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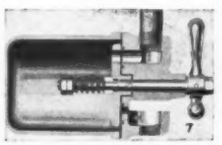
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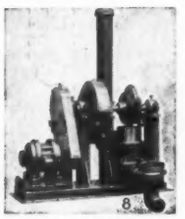
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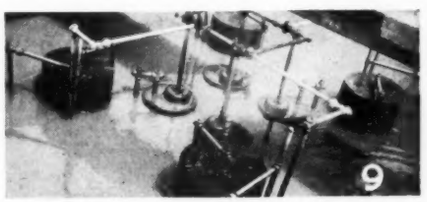
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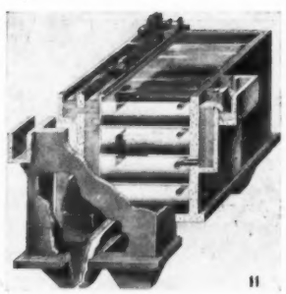
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GAS HAZARDS

Methods of Reducing Such at Sewage Treatment Plants

PART I
OPERATION AND MAINTENANCE

Instructions to Operators and Superintendents

Sewers.

a. Solids should never be allowed to accumulate in sewers to give off gas during their decomposition. Frequent inspection, by means of gas detectors, are suggested to determine if explosive or toxic gases are present. Periodic flushing of sewers is also suggested, particularly in sections at flat grade or near dead ends.

b. Inflammable or volatile liquids, such as petroleum products, oil or cleaning solutions, should not be permitted to gain access to the sewers. Garages, dry cleaning establishments, or any building handling volatile or inflammable liquids should be equipped with traps on their sewer connections to intercept such liquids at their source. Frequent inspections of establishments using such products are required to eliminate this all too frequent source of danger. Persuasive letters or the enforcement of a local ordinance or fire code may be used to enforce their exclusion.

c. As much ventilation as possible should be provided. Any complaint relative to odors from sewers must be given careful consideration, the odor traced to its source and eliminated rather than sealing manholes and thus permitting what could easily be an explosive or toxic gas to increase in concentration.

Plant Odors or Sanitation.

a. All pockets which collect solids should be eliminated and ventilation ducts should be maintained at all points where gas might accumulate. The vapors caused by gasoline and similar products are heavy and should be removed from low points of enclosures, preferably at the point of entrance to the plant, while the so-called sewer gas is lighter than air and must be removed at the top of enclosures (incoming sewers must be trapped to provide positive ventilation). Where provided ventilating systems should be used at all times. Where no ducts or fans are provided their installation should be urged. A mixture of air and inflammable gases in ducts is liable to be explosive, therefore, the blower must be of the non-sparking type suitable for such work and the motor must be as approved by the National Board of Fire Underwriters for hazardous atmospheres.

b. Screen chambers, weir chambers, channels and all pockets where sludge or floating solids may accumulate should be flushed clean at least one daily; more often in summer. Any sludge or supernatant liquor spilled during sampling or drawing should not be allowed to stand to give off dangerous gases or odors. Water or clarified effluent under considerable pressure should be available for these purposes.

c. Scum and screenings should be removed daily.

d. Wet wells at treatment plants or outlying pumping stations should be maintained clean enough, at all times to prevent gas formation.

(The above applies to the removal of sources of gas formation which will, by their toxic effect, lower the vitality of the plant personnel if not present in sufficient concentration to become lethal or explosive. The gases present at sewage treatment plants do not always give warning of their presence by the sense of smell.)

Plant Operation.

a. Care must be exercised in drawing sludge or supernatant liquor from digestion tanks with fixed covers. At no time should the liquid level in this type of digester be lowered to a point where the gas is no longer under pressure. The installation and use of gas storage devices cannot be too strongly recommended to compensate for the lowering of liquid level in digesters. Where gas storage units are provided, no attempt should be made to lower digestion tank levels unless sufficient gas is stored to compensate for such lowering of liquid levels; an alarm on gas holders could be installed to warn when the volume of gas is lowered to a predetermined level. Gas holders or floating covers should never be permitted to come to rest (grounded) unless they are to be taken out of service, in which event they should be purged with an inert gas under competent supervision. (Information relative to purging may usually be obtained from local gas engineers.)

b. Sludge levels should be held low enough below gas domes or outlet pipes to prevent the entrance of solids to gas lines. A float operated pump cut-off switch, alarm, or overflows are recommended to keep the scum level(s) below a predetermined point.

c. A daily examination should be made of the liquid levels of all seals. Any liquid displaced or lost by evaporation should be immediately replaced. The use of a non-evaporating anti-freeze solution is recommended.

d. It is suggested that a chart be set up requiring the daily or hourly notation by the operator or assistants of any data pertaining to gas pressures, sludge levels, liquid or sludge to and from the digestors, gas production, attention to seals or any other data relative to the safe handling of sludge gas. A monthly check of conditions of safety and first aid equipment is recommended.

Safety Measures.

a. All gas handling equipment should be maintained gas tight. Joints should be periodically tested by a soap test for leaks.

b. "U" traps, drips or any outlets into enclosed space should not be permitted. Any such outlets found should be eliminated or, if necessary, vented out-of-doors. Under no condition should they be vented to sewers.

c. All enclosed spaces should be properly ventilated (forced ventilation preferred) so that, should leaks in gas handling equipment develop, no toxic or explosive mixture will be built up. Confined spaces frequently used should be constantly ventilated and less frequented enclosures thoroughly ventilated before use.

d. As a precautionary measure, but far from foolproof where explosion hazards exist, all possible sources of ignition should be eliminated—such as:

Flames: Open lights, matches, cigar lighters, fires, blow torches.
Sparks: From tools, lightning, static, electric shorts, motors.
Heated Materials: Heated metals, hot cinders, glowing tobacco.

The judicious use of "No Smoking" signs is recommended where explosion hazards exist. Too liberal use of these warnings tends to minimize their effectiveness. The use of electrical equipment designed for hazardous atmospheres and spark-proof tools is recommended.

e. Electric motors should be permanently and effectively grounded.

f. It is strongly recommended that whenever it becomes necessary to enter any enclosure—such as a digestion tank—in which an oxygen deficiency or an explosive gas or toxic gas is liable to be found, the following precautions be observed: Completely drain any residue of sludge and purge the tank with water and/or an inert gas. Do this with a minimum of manhole disturbance to prevent possible ignition by sparks. Thoroughly ventilate (force draft if possible, never suction unless by means of spark-proof blowers and motors). A workman (or workmen) must never attempt, or be assigned, to enter such an enclosure unless they are equipped with a gas mask of the hose or oxygen helmet type (never canister) and a safety harness (not simply a rope tied around his body) to which is attached a rope strong enough to support his weight, tied at the top and attended by sufficient man power to pull him out if necessary. Maintain communication between the men in the enclosure and those on top. Rubbers or boots should be worn and a great deal of caution observed to prevent sparks from tools or static electricity such as rubbing or striking metal buttons. Masks and safety harnesses must be kept dry and their condition checked frequently. Never attempt to use this equipment without thoroughly testing. All plant personnel should be thoroughly familiar with their use. Only lights that are approved by the National Board of Fire Underwriters for hazardous atmospheres must be used. These same precautions should be observed with the necessary modifications when entering or working in sewer lines. Air and digestion gas must never be mixed in digesters, piping or any gas handling equipment. When digestors or equipment are placed in service or taken out of service, the entire system must be purged with water, an inert gas, or a combination of the two.

g. Gas and oil burners should be installed and used under local

ordinances or codes and the National Board of Fire Underwriters codes relating to such equipment.

h. A supply of chlorine should be maintained in any process building sufficient for normal demands only. The main supply should be stored in a detached non-combustible building or, if in a room attached to the main building, it shall be of fire-proof construction and separated from the main part of the building by a fire-proof door constructed under the regulations of the National Board of Fire Underwriters. The room or building should be used for no other purpose and should be kept locked at all times to prevent the entrance of unauthorized persons.

i. Two yellow canister masks should be provided for use in chlorinous atmospheres. They should be kept in a dry place which is handy to chlorine storage or use, yet not liable to exposure to chlorine fumes in event of leaks. Every man at the plant should be thoroughly familiar with their use.

Safety Equipment.

The following equipment is recommended for all sewage treatment plants at which sludge gas is collected or burned:

a. A hose mask or oxygen helmet, a safety harness [and two yellow canister masks for use in chlorine gas if included in treatment.)

b. Fire Extinguisher. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Sewage treatment plants should be provided with a suitable instrument for detecting explosive gases and for detecting H_2S. Illuminating gas in sewers may be detected by means of relatively cheap ampoules which indicate the presence of carbon monoxide (CO). A Wolf safety lamp, explosion meter, Orsat apparatuses, or similar equipment are required to test for explosive mixtures. Hydrogen sulphide (H_2S) may be detected by several commercial apparatuses or by a 5% solution of lead acetate.

d. First aid equipment. Personnel employed at sewage treatment plants should have a knowledge of artificial respiration, knowledge of the location of the nearest safety team equipped with an inhalator, and list of doctors and other aids to be called in emergency. (The local gas or electric company usually maintains a safety squad equipped with an inhalator.)

It is suggested that operators and their *assistants* attend first aid meetings and familiarize themselves with first aid and artificial respiration methods. It is suggested that night operators or single operators be required to call the local police station or some other agency hourly and that failure to do this will result in a check-up of the operator's condition by the police. An accident may thus be prevented or a life saved.

e. Manometers or other pressure indicating devices, located at points visible from valves or other controls used to change the levels of digestion tanks, which will indicate gas pressures within the digester and at all other seals. Manometers should be installed in such a manner that the liquid contained therein cannot be blown out to permit the escape of gas into any enclosure.

f. A telephone for use in summoning aid in case of fire, explosion or asphyxiation.

PART II

PLANT DESIGN, PIPING, EQUIPMENT

Sludge Digestion Tanks.

1. *Tanks:*

a. Covered separate sludge digestion tanks shall be provided with means to maintain gas under pressure at all times to allow for reasonable operating fluctuations of liquid or scum levels. Fluctuations in liquid or scum levels will be considered in relation to the volume and moisture content of raw sludge. For domestic sewage, this volume should be from a minimum .3 cubic ft. per capita for plain sedimentation to a minimum of .5 cu. ft. per capita for activated sludge.

b. Covered separate sludge digestion tanks shall be constructed or treated so that they are impervious to gas, and no buildings shall be erected over them.

c. All openings in tanks with fixed covers shall be sealed gas tight. Curtain walls or sampling pipes shall extend at least 6 in. below reasonable operating levels as required in section 1 (a).

d. All closed digestion tanks shall be provided with means for safe disposal of gas as further provided in these recommendations.

2. a. Where gas is collected, domes or similar devices shall be provided at the high point(s) of the digester cover.

b. A safety pressure release with adequate flame protection shall be provided for each collecting dome or floating cover. This device shall be installed to release excess pressure directly from the digester. It shall be designed to operate at a pressure of at least 2 in. of water above maximum operating pressure.

Pipe Lines.

1. *Piping:*

a. Pipe lines to be used for the collection and transmission of digster gas shall be of gas tight construction and shall be pitched with a grade of not less than ½ in. in 15 ft. with drips provided at low points. Consideration should be given to the insulation of exposed lines to prevent freezing of moisture. All piping shall meet the Good Practice Requirements of the National Board of Fire Underwriters.

b. No siphon or "U" taps shall be installed on drips and all automatic drip discharges shall be to a point outside any enclosure. In no case shall this be to any sewer or pipe line.

c. Minimum pipe sizes for gas lines shall be 2½ in. Non-insulated lines exposed to freezing temperature should be double the above capacity. It is suggested that all gas piping be three times its designed capacity.

d. Pipe lines to gas engines shall be suitably protected against flame propagation and excess pressure. All such lines should be independent of all other piping. Sizes and appurtenances shall be determined by the specific engine requirements.

e. Valved by-passes should be provided for all meters.

f. Means should be provided to permit purging all gas handling equipment of sludge gas or air.

g. Means shall be provided to prevent the accumulation of sludge or supernatant liquor in sampling sinks or channels within enclosures.

2. *Valves:*

a. Shut-off valves should be provided for the sub-collection lines for each tank and in the main line before and after the pressure relief and flame traps.

b. Pipe lines or valves shall not be installed permitting the by-passing of flame traps or pressure reliefs.

Equipment.

1. *Pressure Regulation:*

a. Means shall be provided to maintain a minimum working pressure of 2 in. of water in gas piping at the point[s) of consumption.

b. Equipment or devices shall be provided which will confine the fluctuations in working pressure within the gas piping system to a definite limit or range (see also Waste Gas Disposal).

c. Any equipment or device designed for the collection or storage of gas in which excessive pressure may be built up when the flow of gas therefrom is stopped shall be equipped with a device that will permit the escape of gas. It shall discharge at a minimum of 2 in. water pressure over the pressure required in the unit to maintain the designed maximum working pressure within the gas system. Such gas discharges shall not be to any enclosure.

2. *Flame Trap(s) or Arrestors(s):*

a. A flame trap shall be provided close to the service end of all supply pipes, with no connection to a gas consuming unit between the flame trap and source of supply not protected by another flame trap.

b. Flame trap(s) shall be suitably protected from the elements.

c. Where gas engines are to be used, separate flame traps shall be installed on the line (see "Pipe Lines" 1 [d).

3. *pressure Relief(s):*

a. An automatic pressure relief shall be provided suitably protected from the elements.

b. Where gas engines are to be usd, a separate pressure relief shall be installed, of the dry seal type (see "Pipe lines" 1 (d).

4. *Seals and Vents:*

a. Equipment requiring liquid seals shall be provided with indicators clearly showing the liquid levels to be maintained and means shall be provided to introduce an additional supply of sealing liquid.

b. Liquid seals on equipment in locations exposed to freezing temperatures shall be anti-freeze solution.

c. Vents or drip discharges shall be piped to the outside and not to any sewer or pipe line.

5. *Waste Gas Disposal:*

a. A waste gas line shall be provided which will discharge into the atmosphere at a point outside the building at a height sufficiently above ground or surrounding structures to insure proper and adequate dilution, or to a protected burner.

b. The excess gas line shall be free of valves or other possible obstructions.

6. *Waste Gas Burners:*

a. Waste gas burners shall be designed and installed so as to maintain a flame in high winds or rain and shall be provided with a flame trap and a pilot from the outlet side of the main flame trap or an individual flame trap.

b. Waste gas burners shall not be placed nearer than forty (40) ft. from digestion tanks or twenty [20) ft. from any building. They may, however, be placed at least five (5) ft. above flat roofs or two (2) ft. above ridges of gable roofs of buildings provided they are at least fifteen (15) ft. from any higher story or any adjacent building and the roof is of fire-proof construction.

7. *Gas Meters:*

The installation of gas meters is recommended to measure the production and consumption of gas.

8. *Pressure Gages:*

a. A gage, or gages, to show in inches of water (or equivalent) the gas pressure in the digestion tank shall be provided and located so as to be visible at the points of control for the withdrawal of sludge and supernatant liquor.

b. Pressure gages in the line(s) before and after the flame traps and at points of gas utilization are desirable.

c. Manometers shall be designed to prevent escape of gas into any enclosure caused by a blow out of liquid.

9. *Boilers:*

a. Gas and oil burners should be installed and used under local ordinances or codes and the National Boar of Fire Underwriters codes relating to such equipment.

b. Flues from gas heaters shall be separate from building heating plant shimney and shall be carried above roof a minimum distance of three [3) ft. above flat roofs or two (2) ft. above ridge of gable roofs, or if near chimneys an additional height of at least eighteen (18) in. above adjacent chimneys.

c. Siphonage or other type of ventilators on top of flues that will prevent backdraft are recommended.

10. *Gas Holders:*

a. Where gas holders are installed to compensate for differences in liquid or scum elvations in digestion tanks, they should have capacities as required under "Sludge Digestion Tanks 1 (a)." They shall be connected so that any lowering of liquid level in the digester is compensated for by a flow of gas from the holder to the digester. Alarms or cut-off switches are recommended to maintain the volume of gas in the holder above a predetermined minimum.

b. The capacities of gas holders to be used in conection with gas engines shall be considered in relation to the engine requirements.

c. Gas holders of the high pressure type shall include a balancing suction tank and automatic regulators to pump controls.

11. *Ventilation:*

a. Forced draft ventilation shall be provided with outlets at or near the sewage level in enclosed screen chambers, covered sedimentation tanks, and at all points where either heavy or light gas may accumulate. Ventilation by suction is recommended.

b. Ventilating fans shall be of the non-sparking type suitable for hazardous atmospheres. Motors shall be so mounted that no contact is made with the air in ducts or blowers and shall be constructed as approved by the National Board of Fire Underwriters for hazardous atmospheres. Electric motors shall be permanently and effectively grounded.

12. *Housing of Equipment:*

a. Where installed in buildings, heating equipment, flame traps, pressure reliefs, gas meters, etc., shall be located in a separate building or room. The room shall be cut off from the rest of the building by fire-proof walls as approved by the National Board of Fire Underwriters. The entrance to the room or building shall be from the outside and through a door designed to swing outward.

b. The floor of the building or room housing such equipment shall not be located below the ground surface and, if over or under other parts of a building, shall be of gas-proof construction.

c. The room or building shall be ventilated at both the floor and ceiling.

d. The walls of the building or room shall have liberal glass area consisting of thin glass sash. Where, because of exposure, it is necessary to use wired glass, sash shall be so hung that they will readily swing out in case of an explosion. Such sash shall not be secured.

e. All electric wiring, including lights and switches, shall be as approved by the National Board of Fire Underwriters.

f. The use of individual gas heaters is not recommended to burn sludge digestion tank gas.

13. *Safety Equipment:*

a. A hose mask or oxygen helmet and safety harness shall be provided.

b. One 2½-gal. foam or one 15-lb. CO_2 extinguisher should be provided for each 2500 sq. ft. of floor area, or for not over 50 ft. of travel to reach the nearest extinguisher.

c. Gas detectors for inflammable or toxic gases are recommended.

d. A telephone is recommended.

14. *Chlorine:*

a. A separate building or room of fire-proof construction as approved by the regulations of the National Board of Fire Underwriters shall be provided for chlorine storage. It shall be designed solely for chlorine storage, adequately ventilated and its door provided with a lock.

b. Gas masks for use in chlorinous atmospheres are recommended.

Edward F. Shissler, *Chairman,* Leigh Morril, *Secretary*
R. M. Cadman, I. R. Riker.

"SEWER RENTALS"

Recently published is the 120 page brochure on "Sewer Rentals," a production of the American Public Works Association. In it is presented for the first time a detailed analysis of administrative practices employed when sewerage or sewage treatment facilities are financed on a service charge basis. The study which made this document available was undertaken by A.P.W.A. in cooperation with the Municipal Finance Officers Association.

"Sewer Rentals" contains a compilation of sewer service financing practices in more than 100 American cities, with a full discussion of methods and precedures employed. In addition to text, it contains 75 pages of tables of ready reference material covering methods, practices, and results in these cities.

Amongst topics discussed in the brochure are: rate structures; bases of charges; rates; billing and collecting practice; delinquencies; special rate and adjustment problems; disposition of revenues.

"Sewer Rentals" may be purchased at $1.50 per copy from the American Public Works Association, 1313 East 60th Street, Chicago, Illinois.

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PRODUCTS

VENTURI

Venturi Meters for Water, Sewage, Sludge, and Air; Flo-Watch Meters for relatively less important lines; Venturi Rate of Flow Controllers; Loss of Head and Rate of Flow Gauges; Reservoir and Tank Elevation Gauges; Sewage, Sludge, and Air Flow and Ratio Gauges. Chronoflo Meters for Distant Metering. Summation of Meter Totals, Continuous Sludge Weighing Chemical Feeding, Suction Well Level and Pump Control. % Proportioneers % Chemical Feeders for Water and Sewage Treating.

VENTURI METERS—for Water Works and Sewage Plants

Fig. 1. The Venturi Tube

The Venturi Meter is recognized as the standard means of measuring the flow of water in large mains. It consists of the Venturi Tube (illustrated), installed as a section of the main, and the Register-Indicator-Recorder connected to the Tube by two small pressure pipes. For the measurement of liquids containing large amounts of solids, such as sewage or sludge, the *Air Relay Transmitter* is used to prevent the liquid measured from coming into contact with the Instrument.

Fig. 2. Type M Register-Indicator-Recorder (Model D)

Several different types of indicating and recording instruments are available for use with the Venturi Tube. The *Barometric Type Mercury Manometer*, with a flow rate scale graduated directly in flow units indicates rate of flow. The *Flo-Watch*, Fig. 3, for use on main lines in small plants and secondary lines in large plants, records, indicates, and totalizes the flow. The most popular instrument is the *Type M Register-Indicator-Recorder, Fig.* 2.

This Register has the advantage of unusual ruggedness and extreme accuracy. The Type M furnishes three distinct kinds of information; an indication of the momentary flow through the Venturi Tube; a permanent record of this rate upon a large circular chart; the total quantity on a circular counter dial. Each Type M is graduated for the particular Venturi Tube with which it is to be used.

Fig. 3. Flo-Watch Register-Indicator-Recorder

VENTURI RATE OF FLOW CONTROLLER

Fig. 4. Type E Direct-Acting Controller

Effluent controllers automatically maintain constant rate of flow through the filter bed. Several types are available. Features of the Type E Direct Acting Controller (Fig. 4) include: precise control, low loss of head, rigid balanced valve, compact, yet flexible design, powerful "floating piston" actuation, and exclusive molded, tapered piston seal. Venturi Controllers have been standard equipment for many years.

BUILDERS WATER WORKS GAUGES

Fig. 5. Indicating and Recording Gauge

Loss of Head (through filter) and Rate of Flow (Filter Effluent) Gauges are usually mounted on each filter operating table. Indicating and Recording Water Level Gauges are also furnished.

CHRONOFLO METERS AND THEIR USES

Distant Flow Metering

Fig. 6. Chronoflo Recorder

Chronoflo Meters have found a broad application in bringing to a central operating point, from widely scattered locations, accurate records of flow, level, pressure, temperature, gate position, and weight. Chronoflo Transmitters are electrically connected by a simple two-wire circuit to Chronoflo Receiving and Recording Instruments. (Fig. 6).

Reservoir and Tank Elevation Gauges

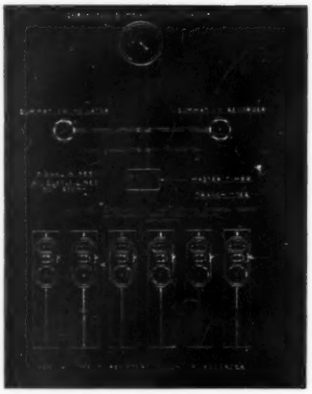


Fig. 7. Totalizing Readings of Six Venturi Meters

in the pumping station and the water works office downtown, continuously indicate and record level in outlying reservoirs, tanks, or standpipes; eliminate the necessity of taking such measurements manually; and promote efficient pumping.

Distant Transmission and Summation

The Chronoflo Meter is peculiarly suitable for adding the totals of various individual meters installed in widely separated locations. (Fig. 7).

Continuous Sludge Weighing

In many sewage plants one measure of efficiency of operation is the weight of filter cake carried from rotary filters to final disposal. A recent development is the attachment of a special Chronoflo Weight Transmitter to a Toledo Automatic Scale, which integrates on a counter the total pounds and records on a continuous chart the rate in pounds per hour.

Raw Sewage Suction Well Level and Pump Control

Builders Iron Foundry Engineers are in a position to work with sewage plant designers in providing Venturi and Chronoflo control devices for this service.

ENGINEERING SERVICE

Inquiries for recommendations covering the adaptation of standard metering and controlling devices are invited. Printed bulletins, illustrating and describing devices mentioned briefly in these pages, are available upon request.

METERING MODERN SEWAGE WORKS*

By ROBERT T. REGESTER

Consulting Engineer, Baltimore, Md.

Flow measurement furnishes an essential part of a treatment process.

In general, the extent to which Venturi metering equipment is provided in sewage works increases with both the capacity of the plant and the completeness, or degree, of treatment to be accomplished.

In many large American cities, where sewage works have been constructed and enlarged within the past ten years, local conditions have warranted the highest degree of treatment. Accordingly, works of the activated sludge type were built.

"Complete" Metering

There is a decided trend toward "complete" metering—especially for works of the activated sludge type. This type of works, providing complete treatment together with the pumping of raw sewage, offers the most numerous applications for metering equipment. The trend is justified from the standpoints of both proper process functioning and operating economy. This tendency is reflected in several more recent designs where provision is made for the parallel operation of similar tanks under different flow conditions. The best combination of variable relationships thereby can be determined. Of course, operation in this manner is intended to be periodic, as the occasion demands, rather than regular. By such means, unfavorable influences can be observed and closer control effected. The works can serve the role of a full-scale pilot plant. In very large works, batteries of similar tanks can take the place of individual tanks so arranged.

Activated sludge works are extensively mechanized and electrified. They present a somewhat complicated arrangement because of the multiplicity of treatment units and process steps. The diagrammatic arrangement here shown serves to illustrate the application of metering equipment for both measurement and regulation of flows to the principal units. This typical layout assumes groups of four units arranged for maximum flexibility and control.

Measurement of Raw Sewage

It is often necessary for raw sewage to be pumped from the outfall sewer to such elevation as will produce gravity flow through the entire plant. Individual centrifugal pumps are metered so that periodical checks can be made on the efficiencies of the respective units. These meters may be equipped with only portable manometers, calibrated directly in rate-of-flow units. On the other hand, individual indicating-recording instruments would show at a glance the immediate performance and would also provide a record of past performance for each pump. This latter scheme is not uncommon in pumping station design.

It is most desirable to provide means for readily ascertaining the total sewage flow to the works. This can be accomplished either by summation (electrically and continuously) of the rates of flow through the individual pump meters, or by providing a separate master sewage meter. In the case of divided flow after pumping, to suit an immediate or future duplicate arrangement of plant, a separate master meter should be provided to serve each half of the layout.

In a large plant it is convenient to have an indication of the total sewage rate of flow at several strategic locations other than at the sewage pumping station. Electrically-operated transmitters and indicators are now used to repeat the summation or master meter readings to such remote points.

Primary Settling Tank Control

It is desirable to have individual settling tanks perform equal duty. As a means of equalizing flows to the units of a battery of these tanks, individual meters with regulating valves can be advantageously used. The valve can be of one of several types, either hydraulically or electrically operated, inserted in the recovery tube of the meter for each tank. This permits the use of a smaller size valve. To minimize the effect upon meter accuracy, the valve should be placed at least two throat-diameters downstream from the throat pressure chamber. The indicating instruments and valve controls can be arranged, for operating convenience, on a control table or panel.

Aeration Tank Control

In the aeration tanks, a properly-proportioned mixture of settled sewage and return sludge from the final settling tanks is agitated and maintained in an aerobic condition by the introduction of compressed air.

The settled sewage, return sludge and air can be metered independently just prior to entering each aeration tank. The sewage and return sludge then mixes upon entering the tank. The air is distributed lengthwise of the tank through porous diffusers arranged along one wall so as to produce a spiral flow of the mixture. When all three meters are arranged at the inlet end of each tank, they can be grouped within the gallery which is usually provided, for the various pipes and feeding channels, along the full width of a battery of aeration tanks.

With an arrangement of independent meters, each meter can be equipped with a regulating valve, as previously described, to permit individual control. For the return sludge, a Venturi rate-of-flow controller may be used, instead of a meter with regulating valve, for each tank. In either case, an automatic control to maintain a predetermined rate can be provided.

A five-dial ratio gauge for the three meters of an aeration tank has been developed. This gauge will indicate, or indicate and record, the rates of flow of air, sewage and return sludge using the first, third and fifth dials, respectively. The second dial will give the ratio of air to sewage, calibrated in cubic feet per gallon. The fourth dial will give the ratio of return sludge to sewage, calibrated in percentage of the sewage flow. The gauges are mounted on control tables which also contain the controls for the respective regulating valves.

Final Settling Tank Control

Final settling tanks remove the floc from the mixture which leaves the aeration tanks. The clarified supernatant liquor passes off as the final treated effluent, to be discharged into the receiving body of water. Meters with regulating valves may be used to equalize the flow of these tanks in the same manner as described for the primary settling tanks. This may only be desirable in the case of numerous units where perhaps one unit is likely to be out of service frequently. Otherwise, the effluent from each aeration tank can flow directly to a corresponding final tank by suitably arranging either stop planks or sluice gates. If these meters are included, they can be grouped with the aeration tank meters in the same gallery, provided that the aeration tanks are of a two- or four-pass type.

For the withdrawal of activated sludge from each final tank, an automatically controlled regulating valve with meter, or a rate controller, is very desirable. There are several other devices, such as adjustable overflow pipes and air lifts, which are also used for controlling the rate of sludge withdrawal. Here again, indicating and recording instruments, controls and push button stations for various motor-driven equipment can be grouped on suitable control tables or panels.

Measurement of Air

In the blower house, each centrifugal blower is provided with a Venturi meter on the intake to measure the flow of free air. These meters are essential for the efficient operation of the blowers and should be provided with individual indicating-recording instruments.

As in the case of the total sewage flow, it is also desirable to provide means for readily ascertaining the total compressed air flow from the blower house, and for repeating this reading in terms of free air to other locations. The previous remarks relating to the master sewage meter apply equally well to a master air meter.

Measurement of Sludge

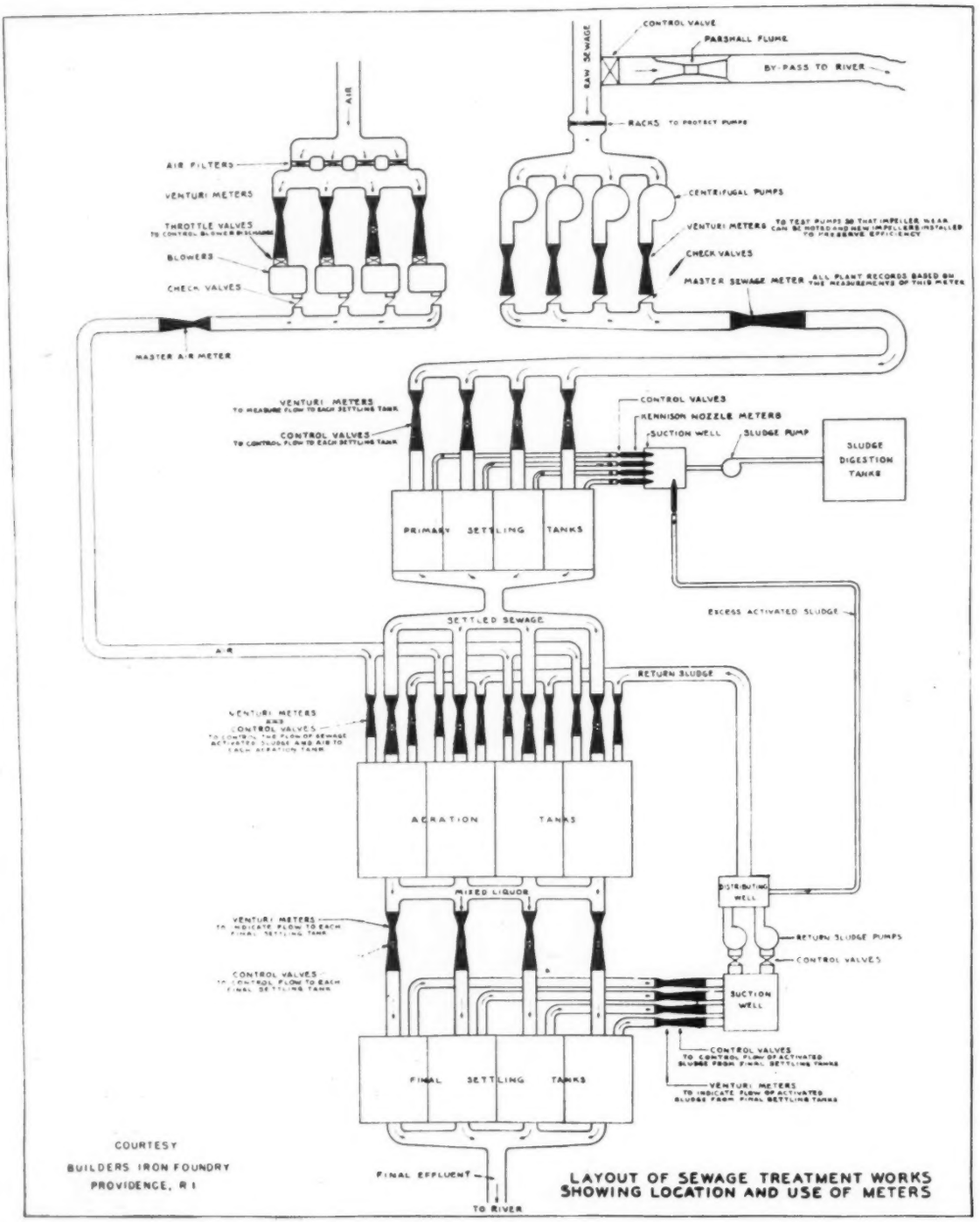
The measurement of sludge has been a problem in sewage works because of the nature of the material and the relatively small flows encountered. The Kennison nozzle meter is now being used for this service. The nozzle is of special free-blowing design, utilizing the depth produced by a shaped outlet as the rate-of-flow function. The nozzle is equipped with an indicating-recording instrument. These nozzles can be used for measuring the raw sludge and the excess activated sludge prior to digestion.

In Conclusion

The cost of providing "complete" metering does not become a major item in the overall cost of sewage works designed for complete treatment. This cost, excluding regulating valves and special control devices, will approximate 3 to 5 per cent of the total cost.

In addition to the applications of Venturi metering equipment already discussed, there are many other special uses for related devices in modern sewage works, especially for control and regu-

lating purposes. These include automatic pump controllers, sampling devices, by-pass regulators, constant liquid level controllers and the like. Many such applications comprise combinations of proven mechanical and electric elements backed by the experience and integrity of reputable manufacturers. However, it is the designing engineer's province to originate and supply these combinations for specific problems. Following in the path of industrial advances in the art of automatic control, sanitary works, too, are being so equipped. Most of the features described herein were embodied in the designs for the Columbus and Baltimore activated sludge works, with both of which the writer has been or is now associated.



Layout of an Activated Sludge Plant Showing Location and Functions of Meters.

ACTIVATED SLUDGE BULKING*

Some Considerations as to Causes and Corrective Measures

By L. H. ENSLOW

Editor, "Water Works & Sewerage"

In presenting this informal discussion, and my own opinions with regard to causes of bulking of activated sludge, I shall also offer suggested corrective measures for bulking. The matter of "sticking my neck out," so to speak, gives me little concern if, by such willingness to expose myself, I can provoke more consideration and study of this most vexing and important problem of operation. And, in my belief, of plant design also.

What Constitutes Bulking?

The first question is—"What constitutes bulking?" When I first entered the sewage field I had heard of bulking sludge but I had no idea what it looked like. I thereafter discovered that there was more than one type of bulking. These types, in my opinion, represent two entirely different causes and effects. One is peptization of sludge floc and the other is really bulking (swelling) of sludge. True bulking of sludge means that the particles have become hydrophyllic. This means that they have taken up water, such as leather will, and swelled to the point that the gravity is so low as to cause the bulked sludge to rise in the final clarifying tanks. When in this condition, slight disturbance and increased velocities will cause it to pass out over the weirs of such sedimentation units. If you examine this sludge closely, you will likely also find that the particles are buoyed up by myriads of tiny gas balloons; i. e. very small gas bubbles of microscopic size. To cite an example, I have observed that salt water oysters subjected to fresh water will exhibit this same hydrophyllic phenomenon of absorbing water. One may say that, like the oyster, the sludge has become "bloated."

Let us consider some of the qualities and characteristics of an activated sludge beginning to bulk. Under the microscope you find that amongst the sludge organisms the protozoa have become sluggish. Instead of working vigorously, (for instance, the stems of bacticella and the like no longer coiling and coming back with a snap as they do when in a healthy condition) you will find that they are lazy and not at their job of assimilating bacteria and what not. I do not know whether they do assimilate anything other than bacteria, but at least they are not active when the sludge is ailing or, is it a case of "vice-versa."

Following this you begin to get peptization or bulking, as the case may be. Bacteria increase, and there is an oxygen deficiency. Nitrates are going down, whereas ammonia is increasing. There is a loss of characteristic brownish color of good activated sludge. In due time the effluent begins to take on the odor of hippuric acid ("hippo" meaning horse). However, the effluent is splendid for a time after bulking of the sludge begins to appear. It is crystalline clear for a while and represents a very excellent effluent. If one could "put the brakes on" at this point and hold the condition, he would have optimum activated sludge operation from an economy standpoint, and as high an efficiency as he could expect. However, the difficulty is that he cannot easily stop the bulking-ball that has started rolling.

The next thing that happens is that the bulking becomes very pronounced. With increase in sewage flow, the sludge blanket is disturbed, and much sludge goes over the weirs into the stream. The liquid portion of the effluent, even yet, is not bad but becomes so in time, if the cause of bulking is not corrected.

What Causes Bulking?

Now let us consider some of the causes of real bulking (swelling), as distinguished from peptization of flocs and milky effluent, such as poisoning of bacteria as enzymes may produce. The universal answer is the deficiency of dissolved oxygen reserve and nitrates in the aerating units or in the final settling tank. The latter may be as important as the former. In other words, the way I look at it, the problem becomes a question of oxygen "banking." Picture an aeration tank (sketched on the black board). Whether by air diffusion mechanically or by air blowing, in the aeration tank liquor you are "banking" dissolved oxygen. With this banked oxygen you can meet demand notes by withdrawing or checking. The notes are the oxygen demand "notes" of the sewage plus that of the sludge in the mixed liquor. If your balance is steady, or on the increase, and your withdrawals are gradually on the decrease through the aerators, you will always have at all points in your "oxygen bank" a residue of dissolved oxygen on which you may draw. Such means solvency and will keep you from going absolutely oxygen bankrupt. Assuming this condition can be maintained, you will never find yourself "in the red"—at least as to performance if not in respect to costs. If you do overdraw your oxygen account but within an hour or so you replace the overdraft, adding perhaps a little surplus, you are still safe from your principal debtor whose initials are B.O.D. In commerce the criterion, of course, is how quickly and adequately you are able to do your banking, that is, how quickly you can make your deposits to meet the on-coming drafts or checks. Just so it is with the balance between oxygen reserve and oxygen demand in an aeration unit, which spells solvency, or bulking bankruptcy.

Another analogy may be made in citing two runners—one a strong runner and one a weak runner. Should the strong runner stub his toe just as he takes off from the starting point, he may have a hard time to overcome the set-back and may even come in, a limping loser. Overcoming such a handicap, even against weak competition, is frequently very difficult. So it is in financing, that is, in making up bank deficiencies; and, so it is in the activated sludge process in making up oxygen deficiencies which reach serious proportions near the influent end of the aeration units.

The rapid oxygen demand of the sewage, as I stated, is the critical thing. This occurs at the inlet end of the aeration unit and represents the sudden demand notes drawn on the oxygen in the bank. I have seen activated sludge plants operating very nicely on very strong sewages, as long as the input remained on an even keel. On the other hand, I have seen activated sludge plants confronted suddenly with varying organic loads, and the process has gone all to pieces with startling rapidity. One would not think that these periodic loadings could disrupt the process the way they do. Of course, what I have said is particularly true of small plants. In large plants it takes much more to cause trouble than in smaller ones, for the reason that your bank is stronger and the "balance" is not so easily upset.

Sludge vs. Liquor.

Too much sludge carried in the aeration tank has an effect similar to too much of an organic load in the sewage coming in. However, in my opinion, the sludge loading does not begin to compare with the influent loading in importance. The reason is that it is a more stable load and is subject to control. It is not flashy unless somebody permits the sludge to become partially septic; then, of course, it has an explosive oxygen demand which is disastrous. The return of supernatant liquor from digesters is a tremendously bankrupting practice as many have learned. More about this later.

Another cause, I think, of activated sludge bulking or perhaps of moderate bulking is a lack of inorganic matter in the sewage. I refer now to material like iron, salts, silt or clay, and other materials which tend to give weight and coalescence to floc of any sort, whether activated or not. As a matter of fact, I consider the activated sludge process to be as much of a natural coagulation process as it is of an oxidation process. The first stages of coagulation and adsorption are by far the most important stages in activated sludge, and if we could chop it off at some point before nitrification sets in (and hold it there) we would have the greatest amount of work for the least number of dollars for operation. Unfortunately, no one has found the formula for this procedure, the nearest to it being the Guggenheim biochemical process which involves a combination of chemical precipitation and bioflocculation.

I might mention that recently there has been considerable work done on the use of silica as a coagulation aid. Perhaps many of you have heard that in water treatment practice silicates may be

* *A paper presented before the Ohio Conference on Sewage Treatment; reprinted from the 12th Annual Report of the Ohio Conference.*

used for improving flocculation with alum and iron, and so in sewage treatment it may well be that something of this nature will be found to play a part in activated sludge coagulation. I cite one indication that silica may have a distinctive bearing. I have frequently observed cases where clay or silt enters sewers as a result of rainstorms. And, almost immediately the coagulation phenomena of activated sludge, the settleability of the sludge, and consequently the important sludge index, seem to improve. I am wondering if perhaps the colloidal silica content of clays may not have a bearing on activated sludge coagulation as it does on alum and iron coagulation. I consider this an interesting problem for some student or researcher to undertake; namely—"The Effect of Various Inorganic Compounds on Activated Sludge Behavior."

Another reason for the bulking of sludge is too little oxygen input in the sludge reaeration channels, if reaeration is practiced. In other words, your bank balance is decreasing rapidly and can decrease extremely fast if you do not keep well ahead of the sludge demand, so to speak. Sludge may have (and frequently does have) a rapid oxygen demand as it comes from the final tanks. In other words, if you are returning your sludge slowly to obtain a concentrated return, you are tending to build up in that sludge an increased and a rapid oxygen demand. Should you not have enough oxygen to take care of the demand immediately, and not enough carrier liquor in which to "bank" this oxygen, you will never catch up. By putting into the inlet of the aeration unit an oxygen deficient sludge you have lost ground before the mixed liquor enters the aeration tank and, in my opinion, that is the reason for the difference in arguments, pro and con, for reaeration of sludge. A new theory is that reaerated sludge must be kept nourished with fresh sewage input. Some will tell you that reaeration is worthless and that it is really harmful, whereas others say that they cannot get along without it. I believe it to be just a matter of the balance of oxygen reserve as to whether or not an operator needs or does not need reaeration of sludge. The British practice is to reaerate and return very thin sludge. The freshness and thinness of their sludges may account for their successes with reaeration.

Another point is the ratio of settleable solids to non-settleable solids in the sewage. I mention this point for the following reason. In Great Britain one of the remedies in sludge bulking is to bypass the long period primary tanks, thus diverting more suspended solids into the aeration units and also securing a fresher sewage, with benefits later to be cited.

Grease and oil have an effect on sludge bulking. Grease or oil mix in with the activated sludge floc and coat the particles, affecting the specific gravity of the sludge if nothing else. Many engineers think it has considerable bearing on the bio-activity of the sludge. Studies now under way will tell us more about this later, but grease separation appears definitely beneficial.

There has been a suggestion that yeast is harmful and results in bulking; that is, yeast from breweries and other places. Some British authorities seem to think yeast is very harmful. I think possibly the yeast growth is the index of something else that is worse. I refer to the oxygen demand, and more particularly to the demand rate of the waste which contains the yeast; but this again is a personal opinion and needs verification. Where yeast is, there is usually a lot of organic matter with it.

Then we come to filamentous bacterial growths, of which we hear so much, such as sphaerotilus and leptothrix. In paper mills they call these growths "slime." I will speak a little more about filamentous growths later. They may be the cause of bulking, but I do not believe they are the direct cause. I think they are indexes, again, of a deficiency of oxygen which is the direct cause of bulking.

Then, of course, there is carbon dioxide. Gas liberation, carbonaceous fermentation and acid production unquestionably have an effect on bulking. Septic sewage and supernatant digester liquor, in my opinion, is probably one of the most serious factors contributing to bulking in the greatest number of plants.

The Effect of Septic Sewage.

I was very much interested in an article that appeared in the July, 1938, issue of "Water Works and Sewerage." Written by Dr. Heukelekian, of the New Jersey Experimental Station, it more or less fights this battle for for me. I have claimed a lot of things that were bad of septic sewage, but I did not know what the New Jersey authorities have revealed—namely, "That once sewage has become septic it will take up oxygen only one-half as fast (approximately) as the same sewage in a fresh condition." In this revelation many will be surprised and take on an increased respect for septic sewage and supernatant liquor. In his studies of the effect of septic sewage on activated sludge, Dr. Heukelekian took septic sewage, boiled it to kill all life and then reaerated it. He found that the same sewage in a fresh condition, treated in the same way, would take up twice the oxygen; that is, would take the oxygen at twice the *rate*, the latter being the important revelation. The amount of oxygen required is not nearly so important as is the rate at which it is required, and the *rate* at which it will be dissolved and "banked" in the liquid phase.

With the above in mind, septic sewage reaching a plant in hot weather reduces the capacity of the storage reservoir of dissolved oxygen by about fifty per cent. For instance, Dr. Heukelekian found that in twenty minutes of aeration, fresh sewage (boiled) would take up 3 parts per million of oxygen (approximately) as against 1.8 parts per million for *septic* sewage treated in the same way. You will note that this is almost two to one. But this is not the whole answer. The important consideration is, that if this happens every twenty minutes from the influent end of the aeration tank through the effluent end of the tank, and if the aeration period is six hours, the effect is considerably multiplied, and interest on the deficit is compounded. Let us put it this way. The dissolved oxygen "balance" is in pretty bad shape before you get to the end of the tank. You have not accumulated anything, because the oxygen is going out at a rate you cannot control, and this rate is faster than it can be deposited. This constitutes about the most interesting disclosure I have seen in the way of an explanation of why it is desirable and many times necessary to avoid septic sewage. We do know that in hot dry weather more than one activated sludge plant operator goes home at night and prays for rain. When he gets rain he knows he is on safe ground, at least temporarily. In my opinion, dilution is one of the best corrections for septic conditions, and it is not a far cry to recommend that a handy creek be bled into a sluggish sewer in hot dry periods.

Supernatant liquor from digestion tanks, if discharged to the inlet of the plant, causes an effect similar to septic sewage, but there is so little of it that you do not begin to feel the cumulative effect that you would if all of the sewage is septic. However, the fact is that supernatant liquor does cause serious upsets of the process. Further, it probably encourages the growth of organisms in the sewage which I believe those of normal activated sludge do not like as associates, and likewise adds toxins.

Peptization of floc can be caused by different things, but you usually find that this condition is caused by a poison of the decolloidizing elements or organisms in the sewage and sludge. In other words, the clotting effect is hurt and you do not get efficient flocculation. Peptization results in a whitish milky-looking effluent.

Correctives

Now consideration may be given to possible correctives and there are several of them. Some of them work and some do not. Some work here; some work there; and some work nowhere. The first thing to try is more air—if you have it. The next thing is lesser amounts of return sludge, reducing the amount of solids in the sludge rather than the volume. If anything, you usually have to increase the volume of return sludge. The third measure, of course, is less sewage. That last seems to be a universal corrective because by-passing has been the most prevalent method of correcting difficulties at activated sludge plants. Adding clay is another method and the use of chlorine still another.

I was extremely interested in another phase of Dr. Heukelekian's paper. His conclusion reads, "The dissolved oxygen level in the activated sludge process is the resultant of the supply and demand of oxygen. The supply is governed by the method and rate of aeration available." Further quoting from his conclusion he says, "Another factor that influences the level of dissolved oxygen is the temperature. As the temperature increases, the amount of oxygen that can be dissolved in the liquor decreases, and at the same time a greater demand exists due to increased biological activity. Thus, the critical periods in the operation of an activated sludge plant appear in the warmer season." If you add to this condition septic sewage, the operator's difficulties are further increased. On both scores the mixed liquor naturally will not dissolve as much oxygen.

Again quoting, "Theriault and McNamee have estimated that 35 per cent of the dried activated sludge is represented by bacterial cells. * * * The bearing of these generalizations on the maintenance of dissolved oxygen in the activated sludge process is obvious. As long as aerobic conditions are maintained, the process of aggregation of sewage colloids will take place, resulting in a well clarified effluent and an active sludge. When there is no dissolved oxygen present the process of aggregation will cease, the opposite process of dissolution will take place, breaking up the aggregated sludge floc."

Dr. Heukelekian then concludes by saying, "Until more definite information is available, indicating that with higher dissolved oxygen concentration a much more rapid purification is brought about, a minimum of 0.5—1.0 p.p.m. dissolved oxygen maintained at all times and in all sections of the aeration tank should be considered as the most economical range."

Other correctives have been seasonal treatment of industrial waste to reduce the load on the plant. Lime have been employed for pH correction, but I will say that my experience has been that the use of lime offers very temporary relief. It does seem to shrink the sludge temporarily, but you soon find that the effluent becomes milky and conditions become unsatisfactory again.

Other methods than by-passing include reaeration, more rapid sludge return, which I have touched on, thickening of excess activated sludge going to the digesters, and stage digestion of sludge, which gives a less objectionable supernatant liquor.

Sludge Thickening.

As to sludge thickening, it was first developed at Los Angeles and later used at Phoenix, Arizona, where it proved a "life-saver." Topeka practices it as does Columbus, and Baltimore is including it in the design of improved works. When sludge thickening is practiced, the sludge is not returned to the raw sewage for settling in the primary tanks where it may become degraded and much of it passes over into the aeration tanks. To my mind, it is extremely questionable practice in activated sludge treatment, and poor economy to return this material to the sedimentation units. A good many people have argued contrary to this, but I have observed many activated sludge plants, have studied them, and have thought about them a lot. When I see this bulky, half-rotten sludge which was put into the tanks as good activated sludge, which laid on the bottom as long as it could and which finally is swept through to the aeration units, I am certain it has a tremendous oxygen demand. It has a tremendous chlorine demand and anything that has a tremendous chlorine demand likewise has a very high oxygen demand. I do not know whether the organisms contained have any effect on the aeration tanks or not, but I do feel that the needless load on an activated sludge plant, caused by this manner of handling sludge, is absolutely unnecessary. It is necessary to take all the load coming to the plant (the sewage) but why should you take a good activated sludge and let it go through partial digestion and put it back into the aerating tanks again during periods of peak loadings?

"Freshening."

Sewer flushing or sewer dilution has always been helpful where septic sewage is the cause of the trouble. I have often said that any operator is fortunate who has the trunk sewer to his plant passing under a brook or stream. By knocking a hole in the sewer and by fitting it with a suitably constructed valve, he is able to realize the value of sewage "freshening" and sweeping sewer flows. It may even pay to install pumping equipment and pump water from a stream, or he might even pump some plant effluent back into the incoming sewage. In my opinion, it may cost less to pump water into the sewer than it does to pump air for aeration purposes and there is little question but that the operator will sleep better at night.

Sludge Return Control.

Now, about sludge return reduction. This seems to be an extremely important item at times. First, the operator keeps down his solids and, second, he draws his activated sludge back fast enough so that he gets more fresh liquid to dissolve more oxygen in the "banking" process. Many of you may be surprised to know that at some plants the return sludge is 50 per cent to 100 per cent by volume. Now why do the operators do this? It is more or less for the same reason that I would like to have a creek pass over the trunk sewer to any activated sludge plant which I would have to operate. The increased return sludge volume naturally will reduce the aeration period, but a 6-hour aeration period does not necessarily mean a thing in the world. One may get better results in two and one-half hours if he knows how. More liquid is delivered to the aeration units, thereby supplying a "blotter" that will absorb more oxygen and hold that oxygen in a higher concentration (probably three times as much) than is possible with strong or septic sewage. Naturally, the total oxygen demand is the same but the operator has been able to put more "money" in the bank. While the total draft remains the same, he avoids oxygen bankruptcy. The whole point is this: Put something into the aeration tanks that will dissolve the oxygen input and then furnish the tank with all the oxygen (air) you have.

There are some operators who say that they want to have a "sludge reserve" for return at augmented rates when troubles appear. Well, all I have to say is this: They are just inviting a lot of trouble. It is ideal (on paper) to have a big reserve sludge tank that can be kept thoroughly activated all the time from which the so-called "shock troops" may be obtained. I know one plant (London, Ontario) working on this basis, but it costs the municipality a lot of money. Actually what those fellows do in London is to return super-aerated sludge to the sewage in the aeration tank. This aerated sludge acts rapidly. When I heard of the theory of zeolite action by sludge, I thought right away about the London scheme, because the operation at this plant is probably as good an example of such action as anything I have seen. Sludge is reaerated for about twelve hours. The contact with the sewage is less than two hours. There is no question but that a good plant effluent results, but the power requirement certainly reflects the high cost of sludge reaeration. And, every so often something has to be done to retard the activity of sludge in the reaeration stage.

Chlorination.

Now this discussion has developed to the point at which I will refer to chlorination and its uses pertinent to activated sludge. First, considerable can be accomplished by chlorinating up-sewer to suppress septic action in sewage. This has been demonstrated better perhaps in Los Angeles County than anywhere else. There it was impossible to treat more than about one-half the sewage flow until up-sewer chlorination was instituted. It was really remarkable how readily the sewage quality was modified and the entire flow could be handled once chlorination was established.

Then, there is return sludge chlorination, which was really "born" in Ohio, and credit goes to E. E. Smith of Lima and to M. W. Tatlock of Dayton for having initiated this procedure.

After Smith and Tatlock told us about chlorination of return sludge the next place at which we heard of its use was at Lancaster, Pennsylvania. I may say, that too much chlorine in the chlorination of return sludge results in peptization, and a "milky" effluent is an indication of such. However, return sludge chlorination certainly has possibilities, as has been demonstrated at other important plants. At Lancaster, aero-chlorination is now being used for grease separation and Mr. Weist, superintendent, has written me that he believes aero-chlorination is better for his purpose than return sludge chlorination, for the reason that it separates grease which previously he had found in his activated sludge. In other words, it is doing two jobs, so to speak.

Phoenix, Arizona, has been practicing concentration of waste sludge for some time, sending it directly to the digester and chlorinating the digester supernatant liquor for return to the aeration units. This has done a lot of good, but now, in addition to this practice, the Phoenix authorities have gone to chlorinating the return sludge.

Now why does this chlorination of return sludge work? I again wish to emphasize the fact that I advance *probable* reasons, largely personal opinions. First of all, bacterial control is accomplished, that is, control of the growth of saprophytic organisms, not the organisms we see on 37 degree plates but those that take up so much oxygen. In this group are the bacteria of fermentations and the sulphate splitters. They produce a lot of CO_2, a lot of hydrogen sulphide, and a lot of trouble for a lot of operators. I liken their presence or absence to cold weather versus hot weather conditions. In other words, if you can suppress bacterial activity through your aeration tanks, these organisms are not present to draw upon the oxygen and to dissipate it rapidly. There is less oxygen demand in the absence of these organisms. For one, I do not believe that saprophytic organisms, as a general rule (certainly not anaerobic organisms), have a place in a sewage plant, other than in the digestion tanks.

The second reason why chlorination of return sludge works is that control is had of filamentous growths. I frankly believe sphaerotilus and other slime forming organisms which we find in activated sludge (like pH and dissolved oxygen) furnish an index of conditions. I believe the deficiency of oxygenation is the real cause of bulking and that filamentous growths, since they will not grow unless a low oxygen balance is had, are principally an indication of a deficiency of oxygen. Chlorine suppresses the rate of dissolved oxygen disappearance and maintains the oxygen balance. In doing this, filamentous growths are controlled. I have seen these biological growths in streams below sewer outfalls, as many of you have, but they disappear just as soon as you begin to get to a stable or balanced oxygen condition. The activated sludge process, with controlled application of chlorine to return sludge, does not "stub its toe" at the inlet end of the aerators and, therefore, deos not come limping down

to the finish line. This practice has accomplished much at Lima, Ohio; Phoenix, Arizona; and Houston, Texas. As a matter of fact, I believe that at Houston the greatest benefits of all have been accomplished by chlorination of the return sludge.

In this connection I will first read from a letter which I recently received from D. Travaini, superintendent, relative to an experience at Phoenix, Arizona. In part he says: "In April of this year we had a beautiful case of bulking. Our convention (Arizona Sewage Works Association) was three days off and we weren't happy with our results. The aerators were so full of filaments that the sludge had completely lost its identity. We ran an emergency chlorine line from our chlorinator to our reaerator and in five days our bulking was completely gone. One hundred pounds of chlorine per day did the trick. The chemical dosage (based on volume of sludge returned) amounted to 5 to 6 p.p.m. of chlorine. Since then we have played around with chlorinating our sludge. Our plant is up to design capacity, but in spite of this fact, by using 75 to 100 pounds of chlorine per day, we have been able to eliminate one aerator from service at a saving of about $50.00 per month, in favor of chlorine over power. We had a serious breakdown in the aerator in question so we had to follow the procedure mentioned but it worked, so we planned to continue this practice."

Houston, Texas, has for some years suffered with an overloaded activated sludge plant. Although at this time the plant is in the process of being enlarged, the boys down there are due a lot of credit for keeping the present plant on as even a keel as they have. I wish to read from a paper by William Pralle, assistant city engineer in charge of sewers, at Houston. This paper, which deals with the operation of the sewage treatment plant, was presented before the Texas Water Works Association. I quote from the paper as follows:

> "Another advantage of an activated sewage treatment plant is that with a little larger operating cost, from about $1.50 to $2.00 per M.G. according to the delivered cost of chemicals, the plant capacity can be increased without spending a young fortune for permanent construction of extensions.
>
> "To make myself clear, I do not mean to hold back on proper capacity to meet average daily flow of activated sludge plants, but do believe in having the plant equipped with a chemical unit to be used in emergencies, and at times when the plants appear to be overloaded.
>
> "The South Side Sewage Treatment Plant in Houston, employing the activated sludge process, has been increasingly overloaded in both aeration and sedimentation capacity for several years. The result has been that the general difficulty, commonly referred to as 'bulking,' was almost continuously present. In the Spring of 1937 a plan for experimentation was adopted, whereby chlorine and chlorinated copperas, or either one of these chemicals as found best by experience, was to be applied during the treatment process.
>
> "Chlorine alone has been applied to the returned sludge at Houston, just prior to mixing with the incoming raw sewage, since May 16, 1937, and the resulting improvement in the plant effluent has been very satisfactory.
>
> Only a portion of the data collected is in form for presentation here, but the following indicates the general improvement so far realized in the plant effluent.
>
> "The average 5-day B.O.D. of the plant effluent for four months prior to chlorine application was 66 p.p.m. and the filterable suspended solids 96 p.p.m. The average B.O.D. determined daily for the two weeks, May 16th to June 1st, was only 37 p.p.m., or almost half. And, the filterable suspended matter for the same period was likewise cut practically in half.
>
> "Chlorine was applied at the average rate of 5.34 p.p.m. to the returned sludge. At this particular plant the volume of returned sludge is, for operating reasons, much higher than is usually practiced in per cent of raw sewage treated. The average aeration time at this plant is practically 2½ hours, so that the reduction of the volume of returned sludge, made possible by chemical treatment, has produced part of the benefits.
>
> "During chlorine application microscopic examination made daily has shown a distinct reduction in number of filamentous organisms in the sludge. * * *
>
> "It has further been definitely found that effective control of chlorine application is necessary for best results, and that over-chlorination will produce undesirable conditions from which recovery is slow."

Then, in his letter referring to an operating record chart attached, Mr. Pralle replies to questions asked by me as follows:

> "You have referred to some of the shortcomings of the chlorine application, or conditioning of returned sludge. Excepting the added cost, the only comment we can offer at present is that a definite 'overdosage' is possible and should be guarded against. The limits of the amount which can be applied with benefit have not been determined, but our experience has shown that a very cloudy appearance of the effluent can be obtained and this has been relieved only by reduction in the chlorine quantities.
>
> "During construction incident to enlargement of our North Side Plant, chlorine application has been in progress for about 90 days. The data obtained are now being compiled, and these promise to given even more satisfactory information.
>
> "Questions of 'Cause and Result' have been found which have not been answered to our satisfaction, so that all comments are welcome. For instance, attention is directed to the greater difference between suspended solids and B.O.D. content of plant effluent during chlorination than prior to chlorine application. (Mr. Pralle is referring to the fact that B.O.D of the effluent improved more markedly than the suspended solids reduction would indicate.—Ed.) Our laboratory methods in all instances have been the same, and two questions are: (1) What has happened to the B.O.D. of those suspended solids which tests indicate are present in the effluent? (2) If the B.O.D. test of the effluent has been vitiated by this small amount of chlorine (as some seem to think is the case) why, then, is the B.O.D. reduction still evident in the analyses of water of the receiving stream below the plant?"

The reason I have read excerpts from Mr. Pralle's paper is to call attention to the fact that as long as the plant is performing better, the effluent is good, and the dissolved oxygen conditions downstream are good, an operator need not be concerned as to the exact technical explanation of the chlorine effect. However, it would be interesting to have more exact knowledge of the effects. This paper, with the accompanying analytical data, indicates that when you have difficulty in keeping your oxygen input up to a satisfactory level, it is a pretty good idea to return a thin sludge at higher rates, than a thicker sludge [longer removed from the aeration cycle) in lesser volume. The interesting thing with reference to the data at the Houston plant is what happened to the B.O.D. of the plant effluent when chlorination of the return sludge was stopped. As Mr. Pralle has stated, after the discontinuance of return sludge chlorination for a period of ten days, just about ten days with chlorination was required to get the plant back in a satisfactory condition. These results and Mr. Pralle's experiences at Houston strengthen my belief that there is a very tangible "something" to the chlorination of return sludge.

[Since this discussion was presented, a very large and important Eastern plant has been employing return sludge chlorination with beneficial results, even during winter months. Another plant (South) also reports good effects, as measured by visible appearances and a more "even keel" type of plant performance, although there is little in the way of analytical data to reveal just why such is the case. Both plants have started low, raised the chlorine dosage gradually until floc peptization appeared and then dropped the dosage back to a non-wasteful point.—L. H. E.]

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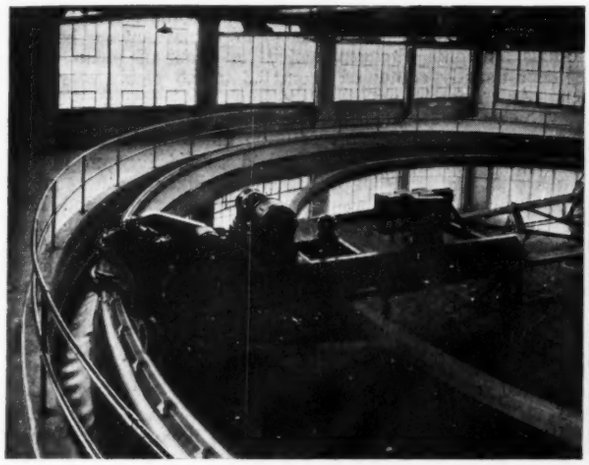

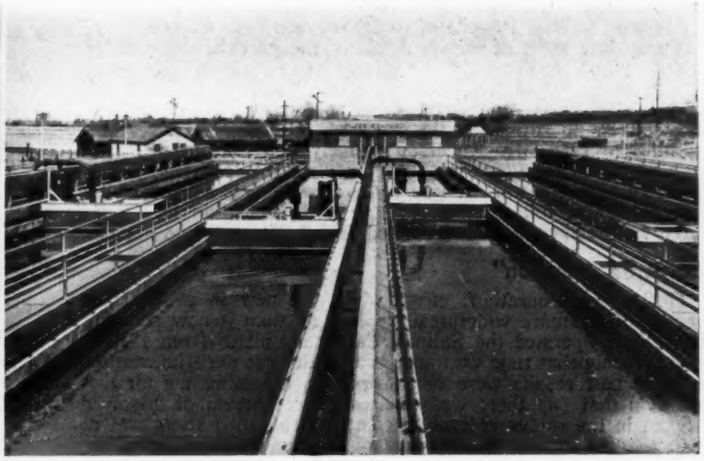

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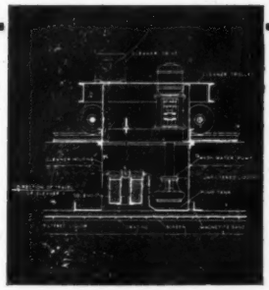
Less settling and aeration tank capacity; less compressed air; a better final effluent.

In Trickling Filters
If ahead, less primary settling tank capacity and less solids to filters. If behind, less humus tank capacity; less final unsettleable solids; a better final effluent.



Above Left—An Automatic Magnetite Filter, installed integral with a Dorr Clarifier.

Left—A section through the travelling cleaner.

Above Right — Magnetite Filter installed in a separate rectangular structure.

AUTOMATIC Magnetic Filters in 1939 demonstrated their value as important steps in all the commonly used processes of sewage treatment. Under all conditions they polished plant effluents to a uniform degree and removed the finest solids at a lower cost per ton than any other piece of equipment operating over the same range.

The Automatic Magnetite Filter consists of a 3 inch layer of carefully sized magnetic iron ore, supported by a non-corrosive screen, and agitated by a moving solenoid which periodically lifts and releases a narrow strip of ore. A counterflow of wash water, introduced as the layer is lifted, carries off the fine particles caught by the bed and renews the life of the filter medium.

It is definitely easier to produce a floc that will filter well than one that will settle. That, in a nutshell, is why Automatic Magnetite Filters make every type of treatment plant do a bigger and better job.

● Write for your copy of the Automatic Magnetite Filter Bulletin

OPERATING CONTROL TESTS FOR THE ACTIVATED SLUDGE PROCESS

By T. R. HASELTINE

Superintendent of Sewerage, Butler, Pa.

The first requirement of the activated sludge process is the maintenance of dissolved oxygen in the aeration tanks. As early as 1926, Harris, Cockburn and Anderson[1] stated this principle of the process very clearly. Their work proved that "the dissolved oxygen adsorbed by the sludge is a constantly decreasing amount from its contact with the inflowing sewage to its discharge from the reactivation channels. The *starting point* of the process of reactivation may be accepted as the point nearest the inflow of the aeration tank at which dissolved oxygen first appears. The degree of reactivation that takes place in the aeration tank is dependent upon the balance maintained between the supply of, and the demand on, the dissolved oxygen and the period of detention as timed from the determined starting point."

Every operator of an activated sludge plant must know that the process is dependent upon aerobic bacterial action. Therefore, it should be evident to all that the presence of dissolved oxygen in the aeration tanks is a prime requisite for the proper functioning of the process. In spite of its self-evident nature some operators may lose sight of this principle of the process, due perhaps to their efforts to comprehend and apply the never-ending stream of articles dealing with the relative merits of pH control, various types and designs of structures and equipment, or the use of chemicals as an adjunct to the process. It is, therefore, very refreshing to read Mr. Anderson's timely and extremely logical articles[2, 3, 4] on the operation and control of the Rockville Center activated sludge plant. It was those articles that led the writer to prepare the following discussion for publication in WATER WORKS AND SEWERAGE that carried Mr. Anderson's two articles.

"Tapered Aeration"

The "tapered aeration" effect while not new in principle, is worthy of far more widespread application than it now receives. The writer operated the Salinas, California, plant[5] from 1930 to 1933. During that time we found, after extensive experimentation, that the best results were obtained by so adjusting the air distribution that (a) there was an appreciable amount of dissolved oxygen in the sludge reaeration compartments, (b) there was at least a small amount at the inlet of the aeration compartments, and (c) the dissolved oxygen gradually increased towards the outlet of the aeration compartments. This required the use of from 55 to 70 per cent of the total air applied in the first half of the aeration tanks. The percentage increased some with high sewage flows, low air supplies, or bulked sludge and visa versa.

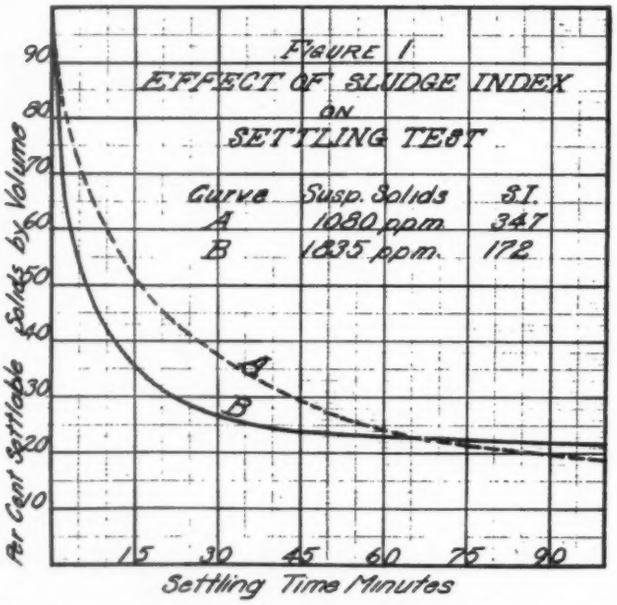


Fig. 1.—The Effect of Sludge Density (Sludge Index) on the Volumetric Sludge Settling Test.

Dissolved Oxygen Tests

To maintain "tapered aeration" it is, as Mr. Anderson points out, necessary to make frequent dissolved oxygen (D.O.) determinations throughout the aeration tanks. However, the writer marvels at the success of Mr. Anderson[4] in using the regular Winkler method for such determinations; first, because one would expect interference from nitrites and, second, because it has been our experience that the sludge floc adsorbed some of the reagents and masked the end point of the titrations. We doubt if the operators of many activated sludge plants would find the regular Winkler method satisfactory. The Report of the Committee on Methods of Sewage Analysis[6] states that "as a rule nitrites will occasion erroneously high results when present in amounts exceeding 0.1 p.p.m. of N. as nitrite. Interference due to nitrites may be expected in dealing with effluents from biological oxidation devices." Whenever the presence of nitrites is suspected the report recommends the use of the permanganate modification of the Winkler method. At Salinas our crude sewage had an organic-plus ammonia nitrogen content of about 65 p.p.m. Our final effluent usually contained from 0.2 to 3.0 p.p.m. of nitrite nitrogen. As might be expected we found the regular Winkler method valueless under such conditions; in fact, we had to use a double strength permanganate solution much of the time.

The accurate determination of the dissolved oxygen in the mixed liquor of the aerators is extremely difficult and requires special apparatus such as was devised by Theriault and McNamee.[7] They state that the usual technique of working only on supernatant liquor from settled sludge gives low results (not subject to empirical correction) due to the high oxygen demand of the sludge itself. However, the writer believes that with proper care it is entirely permissible (for routine plant control) to work on a supernatant liquor and thus avoid the complications of sludge floc or the use of special equipment. It is always desirable to have a margin of safety in plant operation and the errors pointed out by Theriault and McNamee are on the side of safety.

At Salinas we collected samples of mixed liquor from various points throughout the aerators in 2 liter bottles. The bottles were completely filled, stoppered and allowed to stand until 270 m.l. of fairly clear supernatant liquor could be siphoned off into small bottles. The permanganate modification of the Winkler method was then used to determine the dissolved oxygen content of these smaller samples. Ordinarily 5 to 15 minutes' standing of the 2 liter samples would result in sufficient clarification although at times of severe bulking as much as 40 minutes elapsed before the small samples could be siphoned off. On several occasions we siphoned off a second small sample an hour or two after taking the first one and repeated the D.O. determinations. The decrease in dissolved oxygen in the supernatant over the elapsed time was surprisingly small even though the liquor had been underlain by sludge all that time.

Second Operating Requirement

The necessity of maintaining an adequate supply of dissolved oxygen in the aerators at all times, when coupled with the desirability of keeping the power expenditure for aeration at a minimum, leads directly to the second operating requirement—namely, that of keeping the oxygen demand of the mixed liquor at a minimum. The oxygen demand of the mixed liquor is in part due to that of the sewage and in part due to that of the sludge. However, that of the sludge is so much the greater, that of the sewage becomes almost negligible. Grant, Hurwitz and Mohlman[8] proved in the laboratory that (a) mixtures of sewage plus sludge absorb oxygen in proportion to the weight of sludge but with increasing amounts of sludge most of the oxygen demanding material of the sewage is coagulated or adsorbed by the sludge so that very little oxygen is required for the unadsorbed material, and (b) small amounts of sludge reduce the B.O.D. of the sewage almost as rapidly as do larger amounts. Their findings have since been proven in many full scale plants.

It is, therefore, the problem of the operator to first determine

*From WATER WORKS AND SEWERAGE.

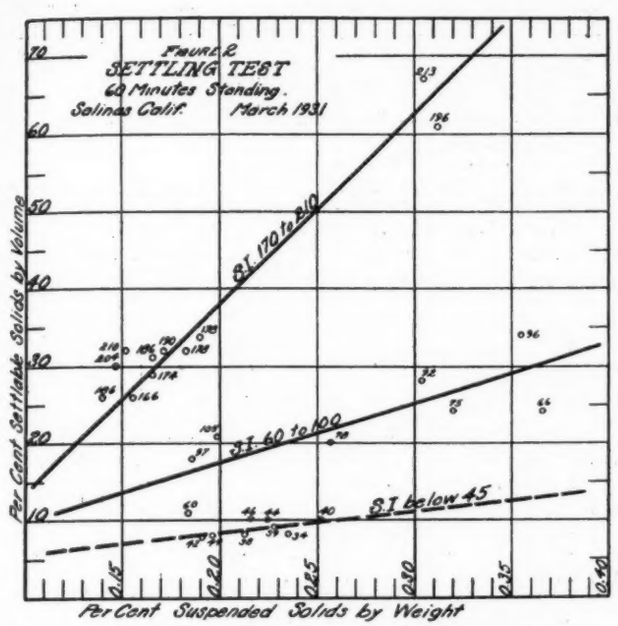


Fig. 2.—A Picture of the Lack of Correlation Between Volumetric Sludge Test and the Gravimetric Test. The Necessity of Taking into Consideration the Density and Settleability (Sludge Index) Is Clearly Evident.

the minimum *weight* of sludge that it is necessary to carry in his own individual plant and then, second, to so control the rate of sludge return that that minimum amount is never greatly exceeded. To solve that problem it would be desirable to have some rapid and accurate means of approximating the *weight* of solids in a given volume of mixed liquor or return activated sludge. As yet no universally satisfactory method of making this determination has been devised. Three methods that have been more or less generally used are (a) settling tests, (b) suspended solids determinations, and (c) centrifugal tests.

All have their disadvantages.

Settling Tests

These are the simplest tests and were the earliest tests used. Samples of sludge or mixed liquor are simply collected in liter graduates, allowed to stand for some given time, and the per cent of settleable solids observed at the end of the given time. In the early days it was usually customary to carry about 20 per cent sludge, after 30 minutes standing, in the mixed liquor. The test is still used and is quite helpful so long as its limitations are kept in mind. Various standing times are used ranging from 10 minutes to 1 hour.

Attempts to correlate the volume of settleable solids, as determined in this way, with the actual weight of the suspended solids in the sample soon showed that no such relationship existed unless the sludge index[2] was also taken into consideration, see Figure 2. "The sludge index (S.I.) is the volume in cubic centimeters occupied by 1 gram of sludge solids after settling 30 minutes." The longer the settling test samples are allowed to stand, i.e., the more the sludge compacts, the less the influence of the S.I. on the results of the test and hence the closer their approximation to the actual weight of sludge solids present. Figure 1 illustrates this point fairly well. However, the rate of sewage inflow to the aeration tanks is constantly changing and tests to regulate the amount of return sludge must be rapid if the weight of sludge solids returned is to be varied in accordance with the sewage flow.

In general the settling test alone can not be relied on except in the smallest plants, and even then only in those small plants that are so amply designed that they are subject to little bulking. In such plants the possible saving in power may not be great enough to warrant the added cost of conducting more accurate test methods.

Suspended Solids Determinations

Suspended solids determinations are the only accurate means of determining the actual *weight* of sludge solids in a given sample of mixed liquor or return sludge. Unfortunately so much time is required for making the determinations that the test is useless as a means of coordinating the hourly rates of addition of sludge solids with the hourly rates of sewage inflow to the aerators. In spite of this handicap the test is extremely valuable and should be made at least once a day at all but the very smallest plants. It should be made at the same time each day; the time selected should be such that the sewage flow for the past several hours has been nearly identical with that of the same hours of each preceding day.

For example, at Salinas[5] we took samples for suspended solids determinations each day at 9 a. m., there being only slight day to day variations in the hourly rates of flow received at that plant between 2 a. m. and 9 a. m. We governed the daily amount of activated sludge wasted almost entirely by the results of these determinations. (The rate of sludge withdrawal from the clarifiers was governed by hourly determinations of the depth of sludge in them. We attempted to keep the rate of withdrawal as low as possible without permitting more than a 1-foot depth of sludge at the sides of the Dorr tanks.) This procedure did *not* accomplish the very desirable end of keeping the suspended solid content of the aerators constant at all times throughout the day. It was probably at a minimum about 11 a. m. when the peak flow started coming in and at a maximum between 10 and 11 p. m. when the flow started dropping off rapidly. However, it did serve to keep the *average daily* suspended solid content of the aerators fairly constant.

Before leaving the subject of gravimetric solids determinations the writer wishes to make a plea for all operators to base their control on *suspended* solids determinations rather than on *total* solids determinations. It is the suspended solids in the sludge that exert the bulk of its oxygen demand. It would be permissible to base plant control on total solids determinations only if the dissolved solids were practically constant. Such is not the case—at Salinas,[5] dissolved solids in the mixed liquor, and plant effluent, ranged from 600 to 1500 p.p.m. under varying sludge conditions.

Centrifugal Tests

This test consists of collecting samples of mixed liquor or sludge in 15 m.l. centrifuge tubes and "spinning" them for a given short time (2 to 5 minutes) in an electrical centrifuge. A hand centrifuge will not serve because of the impossibility of always spinning the samples at the same speed. The writer first heard of this test being used at the Indianapolis plant some eight or nine years ago. We tried it for several months at Salinas. Mr. Anderson[3, 4] has recently reported its successful use at Rockville Center. The test has probably been used at several other plants but it has never been widely adopted. To the writer's knowledge, Mr. Anderson is the first to mention it in the literature.

Like the settling test, the centrifugal test is at best volumetric determination. Nevertheless, it has two outstanding advantages over the gravity settling test. (a) It is extremely rapid and so

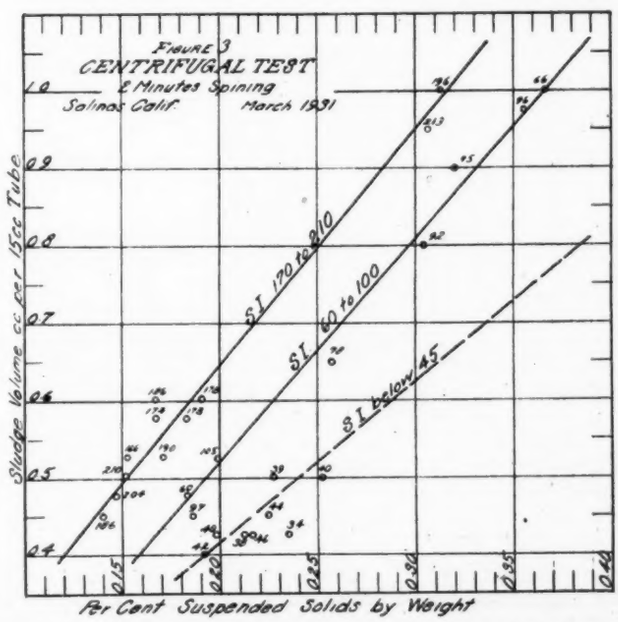


Fig. 3.—A Picture of the Less but Evident Effect of Sludge Index Values on Suspended Solids Tests With the Centrifuge.

may be utilized, with reservations, to control the hourly rates of sludge withdrawal or return. (b) It compacts the suspended solids more and hence there is better correlation between its results and those of gravimetric suspended solids determinations. However, even the results of this test are greatly influenced by the sludge index as is clearly shown by Figure 3. If that fact is not fully appreciated the operator may encounter serious complications in attempts to regulate *weight* of suspended solids in his aerators.

If the test is to be used the operator should first make sufficient trials to prepare a graph similar to Figure 3. Once such a graph is available he may determine the sludge index once a day and from that determination and the graph he can select the desirable centrifugal test results for the more frequent determinations made on the mixed liquor, return sludge, etc.

To substantiate this assumption we submit Table I. Sample 6 was a sample of the return sludge from the Salinas plant; samples 1 to 5, inclusive, were prepared by diluting sample 6 with varying amounts of final effluent that had been collected at the same time.

TABLE I

Sample	Suspended Solids % by weight "A"	Settleable Solids % by volume 30 min. standing "B"	Sludge Index (B/A)
1.....	0.064	5	78.1
2.....	0.172	15	87.2
3.....	0.289	25	87.2
4.....	0.400	35	87.5
5.....	0.549	50	91.1
6.....	1.078	100	92.8

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CONTROL OF ACTIVATED SLUDGE BULKING*

By E. E. SMITH, Superintendent

Water Works and Sewerage, Lima, Ohio

The operation of the Activated Sludge type of sewage treatment plant has the ever present danger of the so-called sludge bulking. Sewage literature abounds with descriptions, reasons for and treatment of this phenomenon. Experiences at the Lima Sewage Treatment Works seems to indicate close correlation between a marked increase in the numbers of bacterial filaments in the aeration units and poor settling of sludge in the final settling tanks, decrease in dissolved oxygen in final tanks, and poor clarification of final effluent. Sludge bulking seems to be the common cause of inefficient and uneconomical operation of activated sludge plants.

During the summer of 1934 when sludge bulking occurred, all previously described remedies were employed. The sewage upon which these remedies were tried was, in common to most sewages of that drought period, unusually strong and high in temperature, with the consequent necessity of efficient purification during the low stream flows.

Experimentation with Chlorine

Sanitary Engineer J. K. Hoskins of the United States Public Health Service had mentioned to the writer some beneficial results to the process following the use of chlorine at the Stream Pollution Investigations Experimental Plant, in Cincinnati. It was decided, therefore, to look into the effects of chlorine gas on the returned activated sludge.

The design of the Lime Sewage Treatment Works was admirably adapted for this particular experiment for the following reasons:

Activated sludge from the final tanks is brought through two separate 12 inch sludge lines from the tank sumps to a sight feed hopper where separate sludge valves control the sludge flow into a 14 inch combined gravity line conveying the sludge 95 ft. to the returned sludge sump. For purposes of chlorination this arrangement permits *good mixing* and a contact period of ten to twenty minutes, depending on the rate of sludge returned. The results obtained from the use of one tank of chlorine, applied without careful control, were so evidently desirable, that arrangements were made for use of W. & T. solution feed chlorinator.

Observations during the treatment of the returned sludge revealed that seven days after the start of chlorination filaments were absent from the sludge. The ratio of *p.p.m. chlorine to each per cent of solids in the returned sludge* is apparently a governing factor in the action of filament removal, because results were not being obtained when that ratio was below 1.00 during the second application of chlorine. No filament removal was noted for the twelve days of low ratio chlorine dosage.

Inasmuch as the last eleven days of application of chlorine during the first experiment and the first twelve days of the second experiment seemed to indicate that chlorine applied below the apparent threshold ratio of 1.00 was without sufficient effect, a further experiment with chlorine was made at ratios of 2.00 or more.

At the Lima Sewage Treatment Works daily microscopical examinations of the aeration tank effluent are made, as well as the usual hourly estimations of percentage of settling solids in the aeration tank effluent. From the indications of these two determinations the chlorine produced a marked reduction of the excessive numbers of filaments. Their complete removal was not attempted, nor did it seem necessary.

Economy of the Process

Air requirements have been reduced to little more than the delivery of the smallest size blower, without regard to variations in sewage flow. It may be estimated that air requirements, without the danger of bulking, should not exceed an average of 0.90 cu. ft. per gallon of sewage. As bulking could be expected usually when the air-sewage ratio was reduced below 1.00 to 1.25 cu. ft. per gallon, the ability to use chlorine as above indicated resulted in a net saving.

The application of air has been as low as 0.62 cu. ft. per gal. daily average and as low as 0.78 monthly average during chlorination. Without the ability to correct sludge bulking so readily and effectively with chlorine such low applications of air would have been unwise and impracticable.

[*Excerpts from an article which appeared in WATER WORKS AND SEWERAGE, October, 1935, here reproduced because other plants have subsequently found the Lima scheme of mild chlorination of returned sludge beneficial in holding oxygen in the aeration units and maintaining performance of the activated sludge process on a more even keel in difficult operating periods. Since 1934 chlorination at Lima has continued to yield beneficial effects.—ED.]

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Midget Chlor-O-Feeders for constant rates. Chlor-O-Feeders definitely led the way to low-cost hypochlorination making it possible to sterilize even the smallest water supply safely, and economically. For plants treating up to 1½ million gallons per day hypo-chlorination is practical.

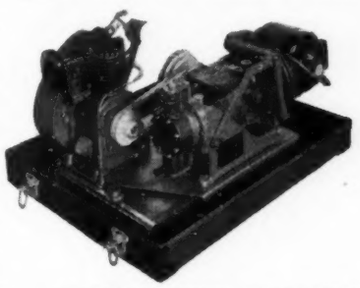

Fig. 1—Portable Emergency Chlor-O-Feeder

Midget Chlor-O-Feeders are furnished for high or low pressure or for feeding into suction side of pump. The device is small; quickly adjusted for different feeds; driven by electric motor, water motor, or by belt connection to water pump R.P.M.

Installation is simple, with aid of our instruction books, and operating costs are low, as anyone able to operate a water pump is fully capable of running Chlor-O-Feeder to satisfaction of Health Departments.

Portable Chlor-O-Feeders—mounted and ready to operate anywhere on instant notice; or mounted in handcase for carrying in back of car; are ideal for emergency use; as standby to temporarily replace gas chlorinator; for sterilization of new or dead end mains; or to augment other units during periods of extreme demand.

Proportional Chlor-O-Feeders for variable flow rates. For many conditions, especially in gravity systems from reservoirs, where flow rates vary considerably from hour to hour, it is essential that Chlor-O-Feeder be controlled by the flow of water so that the amount of solution injected is at all times in proportion.

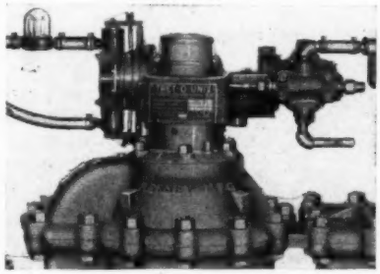

Fig. 2—Proportional Chlor-O-Feeder, Meter Mounted

Proportional Chlor-O-Feeder can be mounted on and controlled by any flow responsive device; standard water meter of any make, size or type; flow responsive rotor; Venturi Tube; orifice plate; or even the reciprocating parts of deep well pumps can be used to "pull the trigger" that sets off the chlorinating discharge. Chlor-O-Feeder can be operated at any point where the water line can be cut to allow installation of meter. It can be operated entirely by water pressure, so does not require expense of wiring. Operation is simple without the attendance of experts.

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Aqua Ammoniation by the "Fume-Proof," "Fool-Proof" % Proportioneers' % method enables savings of half your annual ammonia bill and reduces to one-third the initial cost of chloramination apparatus.

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pH control by proportioning lime, soda ash, sodium silicate, sulphuric or other acids, is made simple by use of these flow-proportional chemical feeders. Highly successful installations, designed by leading engineers, are providing permanent relief from plugged and corroded pipe lines. The growing use of Calgon in water works corrosion control finds frequent use of Midget for feeding sodium hexametaphosphate.

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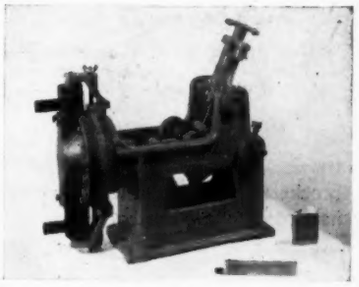

Fig. 3—Standard Ferr-O-Feeder

SWIMMING AND WADING POOL WATER PURIFICATION

Fig. 4—Quadruplex Feeder

Public health demands the closest supervision of swimming and wading pools. Quadruplex feeds hypochlorite for sterilization, alum for coagulation, soda ash for pH control and aqua ammonia for chloramination. %Proportioneers'% multiple units can be had in duplex, triplex, quadruplex or amplified as needed.

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Fig. 5—Visible Sight Feeder

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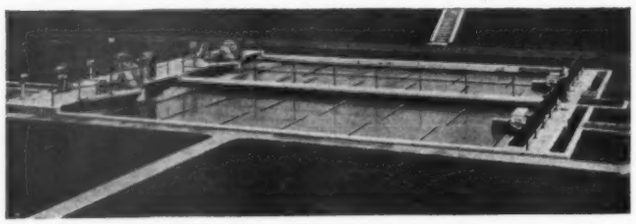
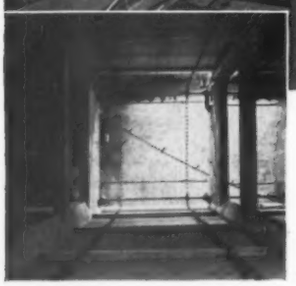
Designed especially for the removal of sludge from rectangular sedimentation tanks, which give efficient and uniform distribution of influent over the cross section of the tank. Jeffrey Collectors, the simplest type of conveyor, consisting of two strands of a heavy pintle type Supermal Chain pass over sprockets at tank corners. Wooden scrapers fastened to the chain, drag along the bottom of tank, pushing the settled sludge ahead into hoppers at influent end. Large carrying capacity permits intermittent operation.



Two double compartment primary settling tanks equipped with Jeffrey sludge removal equipment. Cross type scum remover is shown at the right end of tanks.



View above illustrates an excellent weir construction for secondary basins. View at the left shows covered basins with cross collector for sludge. The cross collector can be driven by a take-off from one of the main collector shafts.

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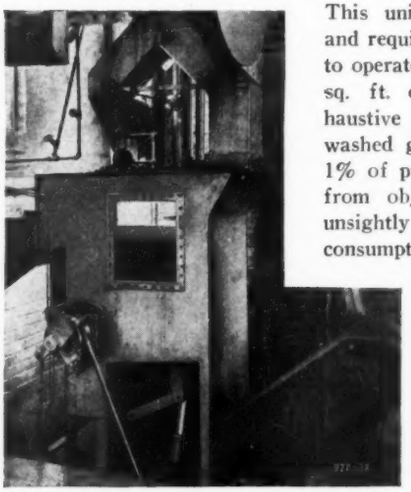
By adapting the Jeffrey diaphragm jig, used for years for cleaning and washing coal, to the washing of sewage grit, we have devised a jig-type grit washer which is so outstanding in accomplishment that it has no competitor.

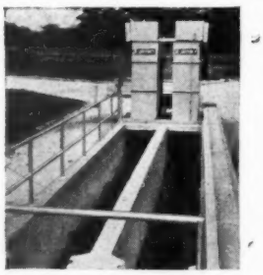


This unit is fully automatic and requires less than 2 H. P. to operate. It occupies only 24 sq. ft. of floor space. Exhaustive tests have produced washed grit having less than 1% of putrescible solids, free from objectionable odors or unsightly appearance. Water consumption is unusually low.

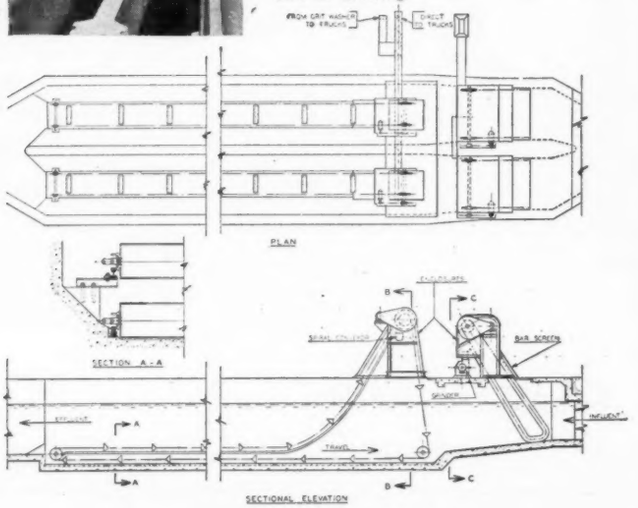
The installation view (left) shows the compactness of the jig-type grit washer. The hand-controlled type washer for small capacities is shown below.

(Conveyor Type)

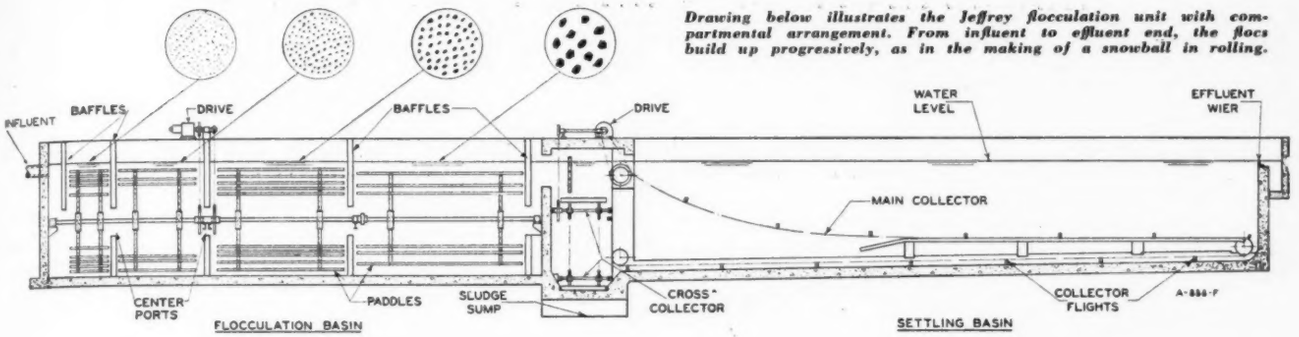
Grit channel conveyors either scraper or V-bucket type offer the most efficient method of grit removal. Either is a continuous conveyor which not only washes and gathers grit but elevates it for discharge. It is not necessary to allow for diminishing cross-sectional area if the grit channels are equipped with Jeffrey conveyors.



The V-bucket conveyor is shown at left and in drawing.



THE JEFFREY MANUFACTURING COMPANY



Drawing below illustrates the Jeffrey flocculation unit with compartmental arrangement. From influent to effluent end, the flocs build up progressively, as in the making of a snowball in rolling.

FLOCTROLS

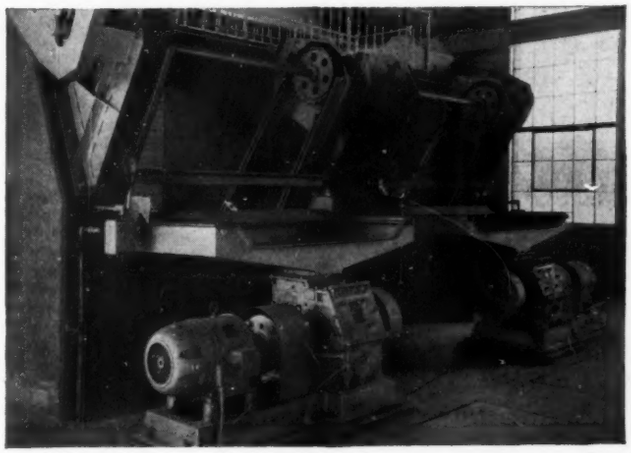
Jeffrey engineers have developed a new flocculation process for the treatment of turbid waters, which obtains substantially complete removal of suspended and colloidal particles in the sedimentation basin, using a minimum of chemical coagulant.

The unit is a rectangular, multi-compartment tank having a paddle wheel mechanism (see line drawing above) in each compartment. The process causes the solid particles to move relative to each other and keeps them in suspension throughout the length of the tank. Degree of agitation is decreased in each step of the treatment.

This new Jeffrey process, which can be used for treating sewage and waste water as well as for water softening and in industrial processing, has these advantages: lower first cost, minimum chemical cost, progressive build-up of stable flocs, continuous sludge removal in separate basin, elimination of short-circuiting, no mechanical adjustments for wide variation in character of influent. Send for engineering data.

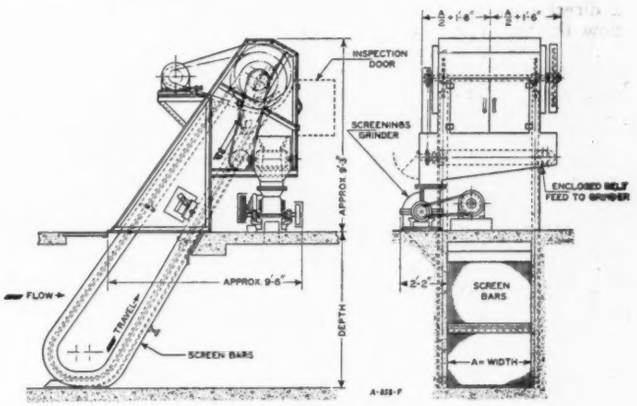
SELF-CLEANING BAR SCREENS AND GRINDERS

With the use of screens and grinders, screenings are collected and disposed of by reducing them to a pulp and returning them to the sewage, thereby solving the problem of final disposal of the screenings. Operation of screen is entirely automatic. Grinder can be either hand or belt fed.



Two bar screens arranged with receiving hoppers for hand feeding screenings to the two grinders. One grinder can be made to serve two or more screens if desired.

The Jeffrey bar screen has a number of features superior to those of any screen offered for this class of service. No sprockets or shafts at bottom of channel, clear opening from side to side in submerged portion, rake teeth pass entirely through the screen, scraper enters sewage back of the accumulated refuse, travel can be reversed, operates continuously or at intervals, electric controls of weather-proof construction.



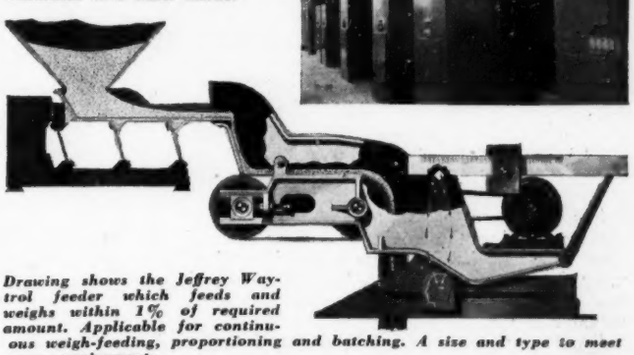
Drawing shows Jeffrey bar screen and grinder details with belt feed.

CHEMICAL FEEDERS (Patented)

Jeffrey-Traylor electric vibrating feeders are well adapted for the feeding of dry chemicals for water and sewage treatment plants. Accurate feeding makes it possible to use the smallest amount of chemicals with a resultant saving in costs.

Simple design with freedom from wearing parts is especially advantageous where continuous operation is essential. Rate of feed can be varied over a wide range. Catalog No. 650 completely describes and pictures Jeffrey-Traylor vibrating feeders.

A group of eleven Type 100 J-T Waytrol feeders (right) feeding chemicals in a water works.



Drawing shows the Jeffrey Waytrol feeder which feeds and weighs within 1% of required amount. Applicable for continuous weigh-feeding, proportioning and batching. A size and type to meet your requirements.

TRITURATION OF SEWAGE SCREENINGS

Operating Experiences at Oneonta's Sewage Treatment Plant

By WILLIAM W. WATKINS

Engineer and Supt., Water Works and Sewage Disposal, Oneonta, N. Y.

In November, 1933, Oneonta, a city of about 13,000 people, in Southern New York State, put its new sewage treatment plant into operation. The plant consisted of a mechanically operated bar screen, settling tanks with mechanical sludge removal, separate sludge digestion tanks and glass covered sludge drying beds.

Mechanical Screening

When the plant was constructed, the screen chamber was equipped with a "Rex" Mechanical Bar Screen, supplied by Chain Belt Co. of Milwaukee. This screen was operated automatically by time clocks, set to start and stop the screen mechanism at such intervals as experience had shown to be necessary.

Varying conditions in the sewage flow caused too much head loss through the screen and corresponding changes in velocity in the settling basins, so, in 1935, the screen was equipped with a direct operated single float which resulted in a more uniform flow through the screen and the settling basins.

At Oneonta, as at most sewage plants, the real problem has not been that of *removing* the screenings from the sewage, but that of hygienic *disposal* of the screenings removed.

Screenings Disposal

For four and one-half years—when weather conditions permitted—we dug ditches and carted the screenings out for burial in what the men call the "graveyard"—a piece of city-owned property adjacent to the plant and about 200 yards away from the screen. If too much ditch was dug in the fall it caved in before it was used up. After the ground froze it was economically impossible to dig more ditches until spring. Consequently in the spring it was necessary to spend a week or more with a crew of men and trucks getting rid of the screenings that had been dumped but couldn't be buried.

The daily average of screenings removed has varied widely from a maximum of 33.4 cubic feet to a minimum of 4.43 cubic feet. And on one occasion (not storm flow), the total screenings for one day was 66 cubic feet.

With such erratic quantities of screenings it was necessary to keep a large amount of open ditch available at all times, as the operator did not have time to dig his own ditches as required. In addition to the extra cost of ditching it was necessary to have a small truck convenient at all times in order that the full cans of screenings might be emptied and not allowed to accumulate for too long periods.

Burying the screenings took about 2 hours of the operator's time, besides the extra help for ditching and the cost of the truck, making the total cost of handling the screenings about $2.00 per day. Since there is no definite relation between sewage flow and screenings handled, costs per million gallons have little meaning, and therefore have not been recorded.

Early in 1937 it was decided that the cost of handling screenings was too high and that something must be done. In coming to this decision, the element of nuisance admittedly had a bearing. After a survey of the field for satisfactory equipment for shredding or macerating screenings for treatment with the sewage, a "Rex Triturator," manufactured by the Chain Belt Company of Milwaukee, was purchased, and installed in June, 1937, for shredding all screenings removed by the automatic bar screen.

The "Triturator" has been operated every day since its installation. It has saved time for the operator, money for the city, and has gotten results in digestion that we had not expected, but which are very gratifying. The digester gas yields have revealed greater uniformity and higher values, consistently.

Benefits from Trituration

From an operating standpoint, the time required by the operator for putting the day's screenings through the Triturator is about one-half hour to one hour—instead of the two hours or more formerly required to bury the screenings. The operator has the saved time to devote to less objectionable and more valuable duties.

From a sanitary or cleanly standpoint, there is no comparison between the old and the new methods. There are now no cans to fill up, to slop over in trucks, to be washed up when empty, or left to draw flies.

From a strictly monetary standpoint, trituration of screenings shows a money saving benefit which can be actually measured. Some of these follow.

The cost of ditching is eliminated. The use of a truck is no longer necessary. These combined items have figured $1.73 per day at Oneonta. Against this is the cost of power and water consumed by the Triturator. Maintenance is not figured in either case, because such has been negligible. The operator has at least an hour more time available each day, and has been able to do some of the work for which we formerly had to hire extra help from time to time.

At an estimated consumption of 25 gallons of water per minute and forty minutes' operation per day, the cost of water at current retail rates is 13 cents per day. A five horse power motor, running at full load, will consume about 4.5 K.W.H. per hour. This figures twenty-eight cents per day at current rates paid. This makes a total additional cost of forty-one cents per day, not counting in depreciation and interest charges.

Gross Savings by Trituration	$1.73
Less power and water cost	.41
Net savings by Trituration (per day)	$1.32

Operating Cost and Savings

From the time that the plant was put in operation until the Triturator was installed, the average daily quantity of screenings has been 12.88 cubic feet. While there is no way of measuring the screenings, it is reasonable to assume that the same average would still hold. To arrive at the cost per cubic foot of triturating screenings, the maintenance cost will have to be estimated, as there has been no maintenance yet except the resharpening of one set of teeth, ten months of service and feeding to the Triturator all materials removed by the bar screen.

Re-sharpening teeth and reserve for parts replacement	$ 22.00
Water cost per year	48.87
Power cost for year	102.20
Time of operator	124.00
Depreciation at 10% per year	79.00
Total yearly cost	$375.07
Average daily cost	1.03
Total cost per cu. ft. screenings	0.08
Gross yearly cost of burying screenings	$813.00*
Gross yearly cost of triturating screenings	375.07*
Net saving by trituration (per year)	$437.93

*Including operator's time.

This means that the savings will have paid for our Triturator in less than two years' time.

Increased Gas Production

In the ten months since the Triturator was installed, gas production has averaged 7,262 cubic feet per day. The production in the corresponding preceding ten months was only 3,022 cubic feet.

When the weight of screenings is considered in relation to the total amount of settleable solids in the sewage, triturated screenings reaching the digester must be given credit for a calculated 50 per cent of the gas increase, if not more.

From this writer's experience, it can be said, with emphasis, that the successful shredding or grinding of screenings is one of the outstanding advances in sewage treatment of the past five years. No simpler disposal can be imagined than the grinding and return of all screenings to the sewage.

SULFIDE DETERMINATIONS BY IMPROVED METHODS

By RICHARD POMEROY, Research Chemist

Los Angeles County Sanitation Districts,
Los Angeles, California

THE problem of overcoming hydrogen sulfide nuisances, both in the care and disposal of sewage and in the treatment of water from sulfurous sources, has focussed attention on methods for the determination of sulfides. Sanitary and water works engineers have been conscious of the need for a quick, simple field method for determining sulfides, which would be at the same time sensitive and accurate. They have also felt the need for a reliable method with which to distinguish the different forms of sulfide.

Measurement of Total Sulfides

The methods which have been most commonly used in the United States for determining total sulfides in water and sewage are: the iodine titration methods and colorimetric methods.

In the colorimetric methods the formation of sulfide precipitates of antimony, lead, copper, iron, and cadmium have been made use of.

The modified iodine method, as suggested by the Committee on Methods of Sewage Analysis of the Federation of Sewage Works Associations (see *Sewage Works Journal*, page 483, 1935), is sensitive and accurate. However, it is not as practicable, simple, or as quick as may be desired for a field method. The colorimetric methods, depending upon sulfide precipitates, are simple and convenient for qualitative purposes, but when applied to sewage are subject to serious inaccuracies, and especially so in the presence of iron salts. Furthermore, they do not reliably detect sulfides at concentrations below 1 p.p.m.

Of all of the methods investigated in this laboratory, that which has been found most satisfactory for a field test, to determine total sulfides in water and sewage, depends upon a reaction which produces methylene blue. Such a method was first suggested in rudimentary form by Emil Fischer in 1883. The procedure is essentially that of adding an acid and an organic base (para-amino-dimethyl-aniline) to the sample and, thereafter, ferric chloride. In the reactions which result methylene blue is produced from any sulfide which may be present.

The Los Angeles Methyline Blue Method

Solutions:

1. Para-amino-dimethyl-anilin hydrochlorid in sulfuric acid. A solution is first prepared containing 20 grams of freshly purified para-amino-dimethyl-anilin in enough concentrated hydrochloric acid to make 100 ml. of solution. Two ml. of this solution are added to a mixture of 50 ml. of concentrated sulfuric acid (c.p.) and 48 ml. of water.
2. Sulfuric acid. A 1:1 mixture of sulfuric acid and water.
3. Ferric chloride. 75 grams of $FeCl_3 :6H_2O$ in enough water to make 100 ml. of solution.
4. Di-ammonium phosphate. 400 grams of $(NH_4)_2\ HPO_4$ in enough water to make one liter of solution.

The above solutions are virtually permanent if kept stoppered.

Procedure:

1. Pipette 7.4 ml. of the sample into a ⅝ in. test tube.
2. Add 0.5 ml. of solution 1.
3. Add two drops of solution 3. Mix the contents by closing the tube with the thumb and inverting slowly once or twice. A blue color indicates the presence of sulfides.
4. Wait for *one minute*. (Extending this interval to several minutes will not affect the result appreciably, but the time should not be reduced below one minute.)
5. Add 1.7 ml. of solution 4 and mix.*

The foregoing basic procedure is valid for sulfide concentrations between 0.1 p.p.m. and 10 p.p.m. For higher concentrations the sample may be diluted.

Color Comparisons:

Two methods are suggested for reading the colors. The first is by use of standard ampules. Standards which can be used for several days may be made with methylene blue, using 5.90 p.p.m. of 100 per cent methylene blue dissolved in pure water for each p.p.m. of sulfide. Permanent standards may be made with copper nitrate solutions, or, better, with mixtures of vanadyl sulfate and cobalt sulfate. If the method is applied to sewage or water of high turbidity, a block comparator should be used.

The second, or "drop method," is as follows: Prepare a second tube according to the same procedure as given for the test, except that solution 2 is used in place of solution 1. Prepare methylene blue solutions containing respectively 1.240 gm. and 0.124 gm. of 100 per cent methylene blue per liter, and provide droppers which will deliver just 25 drops of these solutions to make one ml. Drop the methylene blue solutions into the second tube until the color of the first tube is matched. One drop of the stronger methylene blue solution corresponds to 1 p.p.m. of sulfide, and 1 drop of the dilute solution corresponds to 0.1 p.p.m. This "drop method" is particularly suitable for sewage testing—especially so when the sewage contains large amounts of clay.

Commercial sets including standards and all items required for the test are now available.

Advantages of the Method

The outstanding advantages of this method in contrast to the other colorimetric methods are its sensitivity and accuracy. By using larger samples, sulfide concentrations down 0.01 p.p.m. can be measured. This is of importance in the problems of water supply, because sulfide concentrations of even less than 0.1 p.p.m. may impart pronounced tastes to the water. In water or clarified sewage the accuracy of the method is limited only by the skill of the user in matching the colors. In applying the method in this laboratory in the manner in which it would be used in ordinary field work, the average error with pure solutions was 6 per cent. When applied to raw sewage the error was somewhat greater, with a tendency for the results to be low if the sulfide concentrations are above 3 p.p.m.

Forms of Sulfides

The methylene blue procedure provides a very suitable method for determining the total inorganic sulfide content of water or sewage. Another problem which must be considered is that of distinguishing the different forms of inorganic sulfides. For practical purposes three forms should be considreed—insoluble sulfides, dissolved hydrogen sulfide, and dissolved sulfides other than hydrogen sulfide. Water devoid of suspended matter obviously contains no insoluble sulfides. Ordinary septic sewage will have a few tenths of a part per million of insoluble sulfides, or much larger amounts if iron salts have been added. The easiest way to separate the insoluble sulfides is to add a little aluminum sulfate and an equivalent amount of sodium hydroxide, flocculate and settle. The clear liquor may be used to determine the total dissolved sulfides. In these operations, as in all others in the determination of sulfides, care must be taken to avoid aeration of the sample.

The engineer in most cases would like to know the total amount of hydrogen sulfide which can escape from a sample of water or sewage, and to know the rate at which it will escape. The determination of the total dissolved sulfides, that is, the sulfide determination after removal of suspended matter, measures the amount of H_2S which ultimately can be removed by thorough aeration. At any given time only a fraction of the dissolved sulfides are in the form of H_2S, but if one starts to remove this H_2S more of the other soluble sulfides hydrolyze to H_2S until no more of the non-volatile sulfide remains. The concentration of free H_2S in solution, or the fraction of the dissolved sulfides which are in the form of H_2S, determines the relative rate at which H_2S can escape from the solution. This rate of escape is of great importance, especially in the field of sewage chemistry, for ordinarily in a sewer only a small fraction of the sulfides present escape into the atmosphere above the sewage. In this case the rate of escape is of much more importance than the *total* amount of H_2S potentially available.

Volatile vs. Non-Volatile Sulfides

The fraction of the dissolved sulfides in the form of H_2S is

TABLE I

	Percent of Dissolved Sulfides in the Form of:	
pH	H_2S	Other Sulfides
5.0	99	1
6.0	92	8
6.6	73	27
7.0	52	48
7.4	31	69
8.0	10	90
9.0	1	99

determined by the pH. Table I gives the fractions at various pH values.

The table shows that at a pH of 7.0 about half of the dissolved sulfide is present in the form of hydrogen sulfide—H_2S. From a solution of this pH value H_2S can escape about half as fast as from an acid solution of the same total dissolved sulfide concentration, for in the acid solution all of the dissolved sulfide would be present as H_2S. At a pH of 8.0 the rate of escape would be only 10 per cent as fast as in an acid solution, and at pH 9.0 the amount escaping will be negligible under most conditions.

These figures of rate of escape are of course relative. The absolute rate of escape in a given situation is not easily determined, but experience at this plant indicates that odors are noticeable when the concentration of *hydrogen sulfide* in the sewage exceeds 0.5 p.p.m. Deterioration of concrete and ironwork apparently begins to be serious at about the same point, but copper alloys and lead paints are darkened when in the neighborhood of sewage containing even 0.1 p.p.m. of hydrogen sulfide.

DETERMINATION OF HYDROGEN SULPHIDE BY SIMPLE METHOD

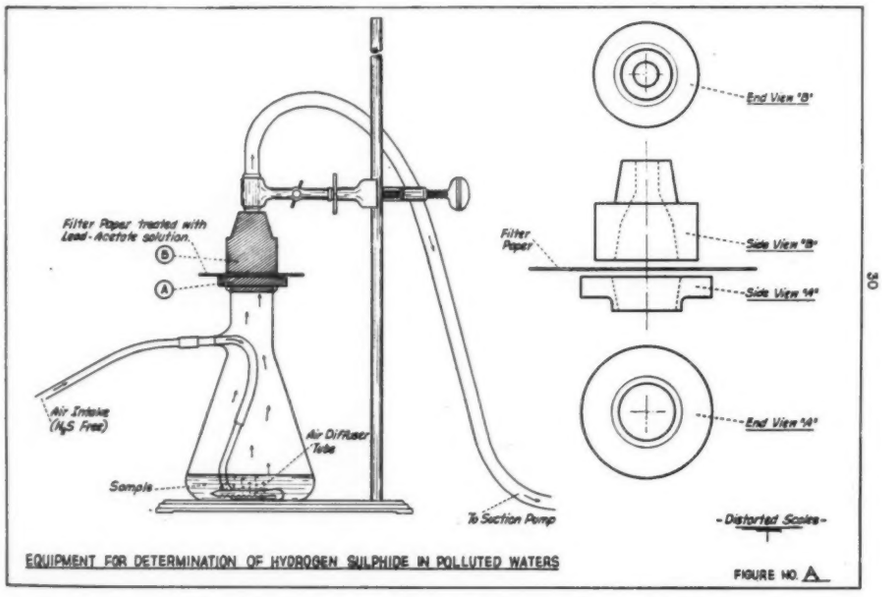
By GEORGE MARTIN, Superintendent of Sewerage

Green Bay, Wisc.

IN MAKING routine determinations of hydrogen sulphide in sewage, sewage gas, and polluted waters it was found that the procedure as described in Standard Methods was not satisfactory, due to the fact that polluted waters and sewage have an iodine demand. Therefore, a modified or special method of procedure was adopted. This special method is based upon the known fact that filter paper treated with a lead acetate solution will darken when placed in contact with hydrogen sulphide. It was found that by making a set of standards, with which any sample might be compared, consistent and fairly accurate results could be obtained.

The Apparatus

The apparatus necessary for making these determinations consists of a standard 500 ml. filtering flask, on the inside of which is placed an air diffuser made of a perforated aluminum tube connected to the flask's side tube by means of a rubber hose. On the outside of the side tube there is attached the rubber air intake hose. The lead acetate paper is held in place on the top of the suction flask between a rubber ring "A," which is a standard Gooch crucible holder for an ordinary two-inch funnel, and a standard Gooch crucible holder "B," as is ordinarily used with a filter flask. "A" and "B" are held together by a utility clamp fastened to a ring stand. The rubber hose which is attached to the glass tubing of "B" is connected to a suction device.



EQUIPMENT FOR DETERMINATION OF HYDROGEN SULPHIDE IN POLLUTED WATERS

FIGURE NO. A

The Procedure

In making a determination with this apparatus the sample to be tested is delivered into the flask directly from a pipette through the aeration tube. Air is then drawn through the liquid for two minutes and by so doing the hydrogen sulphide passes on up through the lead acetate paper, discoloring it. The amount of hydrogen sulphide is determined by comparing the colored lead acetate paper with the standards and converting the results into the desired units.

In order to operate this apparatus satisfactorily it is necessary that there be at least 100 ml. of liquid in the flask. Thus, if the sample being tested is high in hydrogen sulphide, it becomes necessary to dilute it with hydrogen sulphide free water. If it is desired to have the final results in p.p.m., this figure is arrived at by multiplying the color comparison in mg. by 1000 (mg. per liter = p.p.m.) and dividing by the ml. of sample used.

Example: Sample = 10 ml.
Volume of water added to flask ahead of the sample = 90 ml.
Color comparison = 0.05

$$\text{p.p.m.} = \frac{0.05 \times 1000}{10} = 5 \text{ p.p.m.}$$

Gas may be tested for hydrogen sulphide content by passing a known volume through the above described apparatus.

Test Papers and Standards

The lead acetate paper is prepared by soaking filter paper in a 10% solution of lead acetate and drying in an oven until approximately 10% to 15% of the moisture remains in the paper. The paper must then be kept in an air-tight container.

Standards are made from a solution of hydrogen sulphide prepared by generating hydrogen sulphide in distilled water from iron sulphide by the addition of dilute sulfuric acid, the solution being standardized by iodine titration.

[Note: The apparatus herein described won for the author first prize in the Gadget Contest conducted at the recent Convention of the Central States Sewage Works Association.—Ed.]

ACTIVATED SLUDGE THICKENING*

To Improve Digester Performance and Reduce Supernatant Liquor

By D. TRAVAINI

Superintendent, Sewage Treatment Works, Phoenix, Ariz.

Phoenix, Arizona, has an activated sludge plant with Dorrco aerators, and utilizes separate digestion of mixed crude sludge solids and the wasted activated sludge. C. C. Kennedy, Consulting Engineer, who designed the plant, provided a sludge thickener for the purpose of concentrating activated sludge.

The sludge thickener, as constructed, is a circular tank 35 ft. in diameter with an effective depth of 9 ft. at the periphery of the tank with 1 ft. of free board above the water level. The thickening mechanism was supplied by the Dorr Company and consists of a picket fence made of 2-in. pipe on 6-in. centers extending 5 ft. above the bottom of the tank floor. This is attached to the bracing supporting the bottom scrapers. A skimming arm is also provided.

The tank is centrally located and arranged so that waste activated sludge, mixed liquor, plant effluent, primary sludge, or digester overflow liquor can be admitted through pipe inlets at one side of the tank, approximately 18 ins. below the water level.

The original baffle at the inlet was not satisfactory. Short circuiting was so pronounced that it prevented effective utilization of the tank capacity. After considerable investigation, a Sacramento baffle was installed in May, 1933, and ended the short circuiting troubles. We attribute the successful use of the thickener to this baffle and the installation of a Wallace and Tiernan chlorinator made at the same time, the value of which will be discussed later. Before these improvements were made we were prone to look upon the thickener as a liability rather than an asset.

The Sacramento type baffle was developed under the direction of Professor Charles Gilman Hyde more than ten years ago. The structure built at Phoenix consists of a redwood baffle 24 ins. from the wall at the water surface, tapering to 9 ins. at the wall 36 ins. above the intersection of the vertical wall and sloping bottom. This baffle is perforated with 4-in. square openings on 18-in. centers, both ways. Nine inches in front of these openings are suspended wooden baffle boards 10 ins. wide. (See Sketch.)

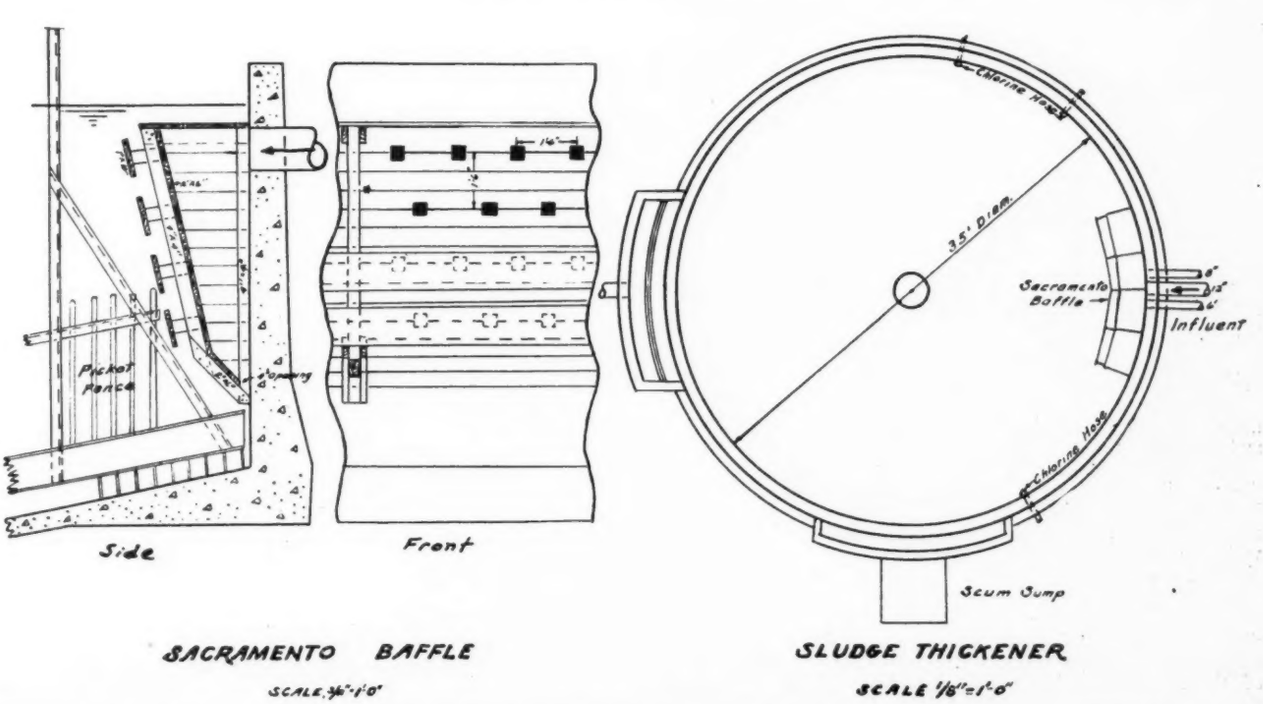
Operation of Thickener

On June 2, 1932, activated sludge had built to a point where wasting could proceed, and the thickener was again placed in service. We were unable, however, to hold the sludge in the thickener sufficiently long to obtain the degree of concentration anticipated when the tank was designed. When we attempted to hold it to increase the solid content to the point anticipated, the sludge would rise and odors became pronounced.

In the early part of October, 1932, we arranged to return plant effluent to the thickener, hoping that the dissolved oxygen in the effluent would retard septic action and thus eliminate odors and allow a longer sludge holding period. This procedure aggravated the short circuiting in the tank and caused the solids in the effluent to increase materially.

The short circuiting in the thickener made it apparent that the original baffle was not efficient and resulted in the installation of the Sacramento baffle. We also installed a Wallace and Tiernan solution feed chlorinator in order to use liquid chlorine to retard septic action. With the chlorinator we anticipated accurate control of chlorine applied to the thickener, which was not possible under the crude conditions in which we had been using lime and chloride of lime earlier.

We devoted our spare time to experiment, to determine the efficiency of the baffle and to find at which points to chlorinate the sludge input in order to obtain the best distribution of chlorine. The results obtained from the baffle were very gratifying. By the trial and error method we selected three points of application of chlorine that gave the best distribution. The



Detail of Sacramento Baffle and Plan of Thickener, Showing Location of Baffle and Points of Chlorine Application

TABLE 1—RETURNED SLUDGE AND MIXED-LIQUOR (SLUDGE) THICKENING DATA. (RESULTS REPRESENT 24-HR. COMPOSITE SAMPLING.)

Date	Gals. of mixed liquor wasted	Chlorine #/24 hrs.	Influent (Mixed Liquor) pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	Thickened Sludge % Solids dry weight	pH
1/18/34	144000	35	7.6	30	1620	0.162	1075	21	20	7.6	—	—
1/19/34	144000	35	7.6	42	1725	0.172	1007	31	24	7.6	4.021	7.6
1/20/34	132000	35	7.8	50	1823	0.182	1012	31	28	7.8	4.287	7.8
1/21/34	144000	35	7.8	55	1342	0.134	1000	16	38	7.8	3.937	7.8
1/22/34	132000	30	7.6	50	1865	0.186	938	42	36	7.6	3.571	7.8
1/23/34	234000	45	7.6	47	2339	0.234	1020	26	26	7.6	4.120	7.6
1/24/34	288000	53	7.6	42	1618	0.162	1074	37	46	7.6	4.090	7.6
1/25/34	207000	50	7.6	54	2232	0.223	1015	26	32	7.6	3.529	7.6
1/26/34	132000	50	7.6	40	1065	0.106	1045	13	16	7.6	3.996	7.6
1/27/34	172000	41	7.6	32	1255	0.125	909	38	30	7.6	3.827	7.6
1/28/34	158480	40	7.6	30	1863	0.186	1010	27	22	7.6	4.090	7.6
1/29/34	158400	36	7.8	28	1652	0.165	995	13	16	7.8	3.684	7.8

Date	Gals. of returned act. sludge wasted	Chlorine #/24 hrs.	Influent (Returned Activated Sldg.) pH	% by volume 1 hr. settling	Suspended Solids p.p.m.	Suspended Solids % dry wt.	Effluent Total Solids p.p.m.	Suspended Solids p.p.m.	B.O.D. p.p.m.	pH	Thickened Sludge % Solids dry weight	pH
2/9/34	70500	60	7.6	98	5243	0.524	1210	36	106	7.6	—	—
2/10/34	60300	65	7.8	88	5651	0.565	1163	43	126	7.8	3.618	7.8
2/11/34	45200	65	7.8	99	6920	0.692	1090	28	95	7.8	3.684	7.8
2/12/34	38500	55	7.8	99	7848	0.785	1215	45	152	7.8	3.262	7.8
2/13/34	54100	65	7.8	98	8132	0.813	1230	52	166	7.8	4.127	7.8
2/14/34	19200	50	8.0	98	7337	0.734	1140	38	120	8.0	4.004	8.0
2/15/34	30300	55	7.8	98	8243	0.824	1125	45	138	7.8	3.529	7.8
2/16/34	11040	40	7.8	98	9130	0.9130	1110	32	95	7.8	3.280	7.8

chlorine hoses are submerged 3 ft. below the liquid level in the tank. One point of application is 13 ft. along the periphery of the tank from the west end of the baffle. The other two points are 9 ft. and 18 ft., respectively, along the periphery of the tank from the east end of the baffle. (See Sketch.)

By varying the quantity of chlorine solution applied at the points mentioned even distribution of chlorine was maintained in the surface liquor, where desired, rather than in the sludge proper.

With this preliminary work completed, during the early summer we tried concentrating primary sludge in combination with mixed liquor taken from the aeration tanks; then primary sludge with returned activated sludge, and then returned activated sludge alone. Very good results were obtained in each instance, but the trials with mixed-liquor seemed the best.

Scheme Giving Best Overall Results

In August, 1933, we decided to try concentrating mixed liquor only, a method suggested by R. F. Goudey.[1]

Our object was, that in summer the primary clarifier influent is stale and we felt that by adding to the crude sewage a sizeable flow of effluent from the thickener, containing dissolved oxygen and some residual chlorine, it would improve plant operating conditions. The amount of thickener effluent would naturally be much greater when concentrating sludge from mixed liquor than when concentrating returned activated sludge and therefore the greater benefit to the crude sewage.

The results obtained by thickening mixed liquor taken from the aeration tanks were so satisfactory that we soon adopted it as routine operation. The primary sludge is concentrated to approximately 5 per cent in the primary clarifier and is mixed with the thickener sludge by pumping sludges from both tanks simultaneously to the digesters.

In Table No. 1 analytical data of thickener operations are given for mixed liquor (above) and for "returned" activated sludge from the clarifier (below). Table 2 shows the solids content of the sludge at various depths. As a result the installation of the Sacramento baffle and chlorination, we can maintain a clear overflow with the sludge blanket within 3 ft. of the liquid level, when wasting 200 gpm. or less of mixed liquor or returned sludge through the thickener. The cost of chlorination is considered very nominal considering its advantages.

TABLE 2—SLUDGE CONCENTRATION DATA

	Depth from liquid level in ft.	Nov. 3 1933	Dec. 11 1933	Jan. 20 1934	Feb. 11 1934
% Solids in sludge at depth shown	3	—	0.25	0.27	0.810
	4	0.50	0.50	0.70	1.02
	5	1.20	1.05	1.15	1.35
	6	1.04	1.25	1.37	1.72
	7	1.20	1.40	1.55	2.38
	8	1.40	1.70	2.10	2.87
	9	3.50	3.25	3.75	3.05
	Cone	4.08	4.21	4.28	3.68

Conclusions

Since we installed the Sacramento baffle and eliminated short circuiting, and since we started to chlorinate the top liquor to retard bacterial action and thereby control septicity, the thickener has operated satisfactorily and accomplishes the purpose for which it was designed, viz.: reducing the volume of sludge and hence the volume of supernatant liquor which is so disastrous to the activated sludge process. Likewise the need for greater digester capacity.

[1] "A New Method of Concentrating Activated Sludge," R. F. Goudey and S. M. Bennett. WATERWORKS AND SEWERAGE, May, 1933.

[NOTE—This scheme of sludge concentration has since been adopted at other activated sludge plants—notably Lancaster, Topeka, Baltimore, New York City.—Ed.]

WALLACE & TIERNAN CO., INC.

Manufacturers of Chlorine and Ammonia Control Apparatus
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"The Only Safe Sewage Is a Sterilized Sewage"

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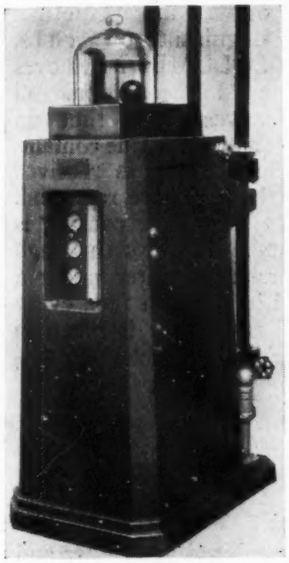
CHLORINATION OF SEWAGE

Of all chemicals used in sewage treatment, chlorine has by far the widest application. From simple disinfection to use as an adjunct to the most involved treatment process, chlorination has for many years been the versatile and valued aid of the man concerned with sewage disposal.

Chlorination is employed to stabilize raw sewage, control odors along trunk sewers or at treatment plants, protect masonry structures from disintegration, increase efficiency of filter beds and prevent filter ponding, improve sedimentation and remove settleable solids, improve sludge digestion, prevent bulking in activated sludge plants, reduce biochemical oxygen demand and retard putrefaction in the receiving water course, disinfect effluents before discharge and is a necessary adjunct to nearly any process of chemical precipitation.

DISINFECTION

Regardless of what the preliminary process of sewage treatment may be, disinfection of the effluent before discharge has come to be regarded as a necessity. Protection of water supplies, of bathing places and of shellfish propagation beds all require efficient disinfection. That chlorination offers the one practical and effective means of sewage disinfection today is universally acknowledged by sanitarians and public health authorities.



Master Visible Vacuum Chlorinator — W&T Visible Vacuum Control is now available in equipments ranging in capacity from .03 to 6000 pounds of chlorine per 24 hours.

ODOR CONTROL

Control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sulphide (the gas responsible for these obnoxious odors) or prevention of its formation by controlled application of chlorine, is not only practical but also satisfactory in results and economy of operation.

B. O. D. REDUCTION

In order to prevent production of odor nuisance, foul appearance and death to fish life in streams receiving the effluents from sewage disposal plants, chlorination for B. O. D. reduction has become increasingly popular. Offering, as it does, a simple, easily controlled and relatively inexpensive means of supplementing other purification processes during periods of low stream flow or for permanent use at a plant where the dilution factor is low, chlorination has, in many cases, eliminated the necessity for extensive additions to the regular treatment works.

IRON SALTS IN SEWAGE TREATMENT

Lowered cost of chemicals and other contributing factors have greatly increased the popularity of iron salts for various uses in sewage treatment, odor control, sludge conditioning, chemical precipitation, etc.

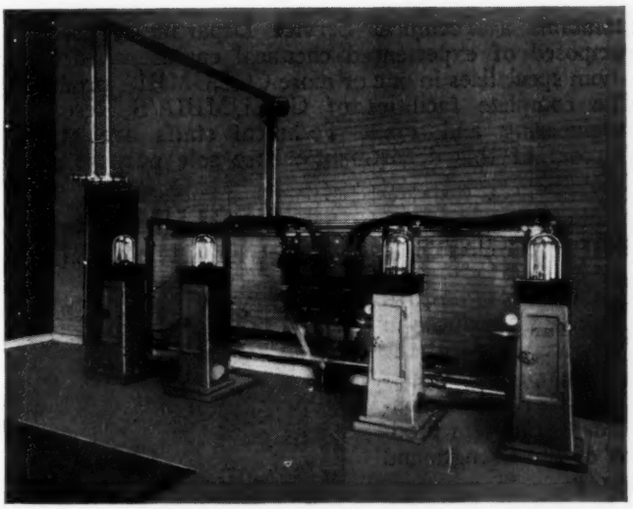
In whatever form this treatment may be adopted, such as the manufacture of ferric chloride at plant site, the addition of ferric chloride or of ferric sulphate directly, or the use of chlorinated copperas, W&T are prepared to furnish the necessary equipment. Complete details on request.

W&T field representatives will gladly confer with you about any specific problem relating to the application of chlorine or iron salts in sewage treatment. Technical publications and literature are available on request.

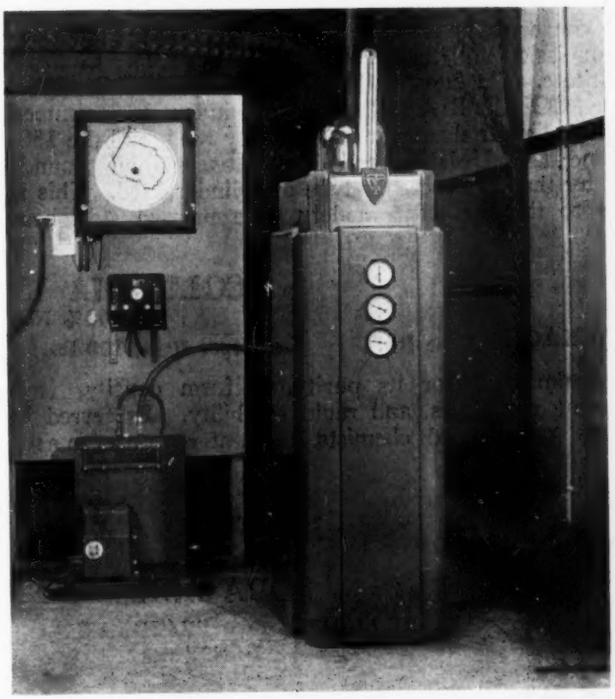
CHLORINE FLOW RECORDERS

Chlorination records form an important log of plant operation and are indisputable evidence that proper application of chlorine were made. Periodic visual inspection will not reveal when equipment may have been temporarily out of service for cylinder change-over, cleaning or any other cause.

The W&T Chlorine Flow Recorders meet the need for continuous automatic flow recording. These Flow Recorders are of two types: the "Direct air transmission type" for continuous recording of chlorine flows, and the electrically operated type which provides indicating, recording and totalizing. The electric type is particularly suitable for use with a battery of chlorinators.



Installation of four Visible Vacuum Chlorinators at the New Haven, Conn., Sewage Disposal Plant.



Panel Mounted Direct Type Recorder with standard Type W&T Visible Vacuum Chlorinator

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WITH its plant centrally located and served by four railroads, COLUMBIA offers excellent service to all consuming centers, by direct shipment from plant on carload quantities and through conveniently located distributors on less than carload orders. COLUMBIA maintains a Technical Service Department, its staff composed of experienced chemical engineers, each of whom specializes in one or more COLUMBIA products. The complete facilities of COLUMBIA'S Research, Engineering and Plant Technical staffs are at the disposal of this department whose sole purpose is to cooperate with users of COLUMBIA products on their applications, qualities, and methods of handling to meet individual requirements. Analyses and samples are available to interested concerns without cost and on request, a member of the Technical Service Department will call for personal discussion without obligation. The COLUMBIA Technical Service Department is particularly well qualified to assist customers in the design, installation and operation of equipment or processes involving the use of Liquid Chlorine.

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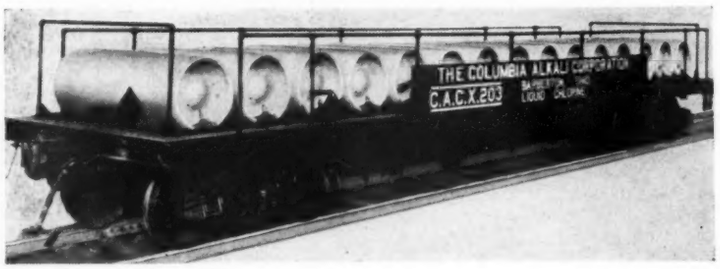
SHIPPING UNITS • 30 ton single unit cars • 16 ton single unit cars • 15 ton multiple unit cars • 150 and 100 lb. cylinders



COLUMBIA Liquid Chlorine is produced in a modern plant with the most improved equipment, assuring the consumer a uniform product of full strength and purity.

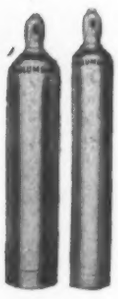
The equipment for the distribution of COLUMBIA Liquid Chlorine conforms to standards of the Interstate Commerce Commission and the recommendations of The Chlorine Institute. The latest and best type of cylinders are used. The COLUMBIA 100-pound cylinder is seventeen pounds lighter than others commonly used, and the 150-pound COLUMBIA cylinder is twenty-nine pounds lighter than the ordinary type of cylinder used. This is due to the fact that modern type pressed steel construction is used. Perfect valves are of vital importance to efficient and safe handling of Liquid Chlorine. Cognizant of this, COLUMBIA removes and reconditions all valves every time an empty Chlorine container cylinder is received at COLUMBIA's plant. The valve seats are reground. Any worn or defective part is replaced. The packing is changed for new. After reassembly, follows thorough inspection and testing by immersion in water under a pressure greater than is required in use. In fact, every precaution that engineering skill can devise is taken to assure consumers of COLUMBIA Liquid Chlorine maximum valve efficiency.

COLUMBIA LIGHT SODA ASH

99-100% Na_2CO_3 (58% Na_2O)

PACKAGES • Bulk • Paper Bags, 100 lbs. • Burlay Bags, 200, 300 lbs. • Barrels, 300 lbs.

Recommended for its purity, uniform density, free-flowing properties, and rapid solubility. Preferred by many experienced chemists for water treatment. COLUMBIA Soda Ash is also produced in Feather and Dense grades for specific uses.



OTHER COLUMBIA PRODUCTS

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LIGHT • FEATHERED
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CALCIUM CHLORIDE
FLAKE • LIQUID • SOLID

PURGING AIR DIFFUSER PLATES WITH CHLORINE

By W. M. FRANKLIN, Superintendent

Water and Sewage Plant, Charlotte, North Carolina

The five aeration units at the Irwin Creek Sewage Treatment Plant, at Charlotte, N. C., are of the ridge and furrow type, equipped with diffuser plates. Manometers register the cubic feet of air per minute being delivered to each aeration unit. A master air-meter records the total quantity of air applied.

In the early summer of 1938 the diffuser plates in all the units became so badly clogged that it was impossible, even with two blowers in service, to get enough air through them to maintain proper aeration. All units were then cleaned out, as rapidly as they could be spared from service, and the diffuser plates scrubbed with muriatic acid. This had been the practice since the beginning of plant operation. All but two of the units responded reasonably well to this treatment. Units, No. 1 and No. 5, became clogged again after a few weeks operation. The acid cleaning was repeated in these two but with no better success. The normal average delivery of air per unit with one blower in operation is about 700 to 750 cubic feet per minute. The delivery of the diffusers in No. 5 unit was down to an average of 450 ft. with one blower in service, and with two blowers in parallel an average of 750 ft. could be maintained—(see Fig. 1). Since it was impossible to increase the air delivery in these two units by throttling the other three, and thus increasing the pressure of the air in the header feeding the diffusers, we were in something of a "mess."

At this time the plant load was heavy and the removal of one unit from service for a period long enough to empty and clean was extremely hazardous.

We decided to follow a suggestion previouslv made by L. H. Enslow of the Chlorine Institute. This suggestion was to add chlorine (as gas) to the air headers leading to the diffusers, with the idea that the chlorine would destroy algae growth in the plates, and might attack other clogging materials.

We first viewed this plan with alarm, fearing that the presence of chlorine gas in the air lines might cause corrosion, especially in the small feeder lines. Finally it was decided to try chlorine anyway. A tap was made in the header feeding No. 5 unit and chlorine fed into the air flow at the rate of about 17 lbs. per day.

In Fig. 1 the delivery of the diffusers in No. 5 aeration unit, in cubic feet of air per minute, has been plotted from August 22, 1938, through Oct. 9, 1938. Dotted lines indicate the period during which two blowers were operating in parallel, the solid lines indicating the period during which only one blower was in operation. Note that on Sept. 15 chlorine was fed for about four hours at the 17 lb. per day rate with two blowers operating. After the chlorine was cut off the two blowers remained in service the 18th. At this time one blower was removed from service and on the 19th the chlorine application was continued until the 150 lb. cylinder was exhausted on Sept. 25. The second blower was put on the line on the 24th with the idea that the increased velocity through the plates might help in opening up the pores. On the 30th normal operation was resumed with one blower.

Note the increase in air delivery during the period following the first "shot" of chlorine until the end of the curve on Oct. 9.

Actually, the chlorine brought about an increase of approximately 66% in air delivery with one blower in service and 53% with two blowers in service, as is shown by the curve. Needless to say we were so well pleased with the results that we immediately cleaned No. 1 unit with one cylinder of chlorine getting equally as gratifying results as was the case in the No. 5 unit.

At this date March 1, 1939, the air delivery of the diffusers in both Unit No. 5 and Unit No. 1 is about 750 cubic feet per minute and no detrimental effects from the application of chlorine have been observed.

It is our theory that the action of the chlorine not only cleaned the surface of the diffuser plate but also cleaned the pores *from the inside out*, removing organic matter from interior pores of the plate which could only otherwise be removed by a heat treatment, or long soaking in an acid bath.

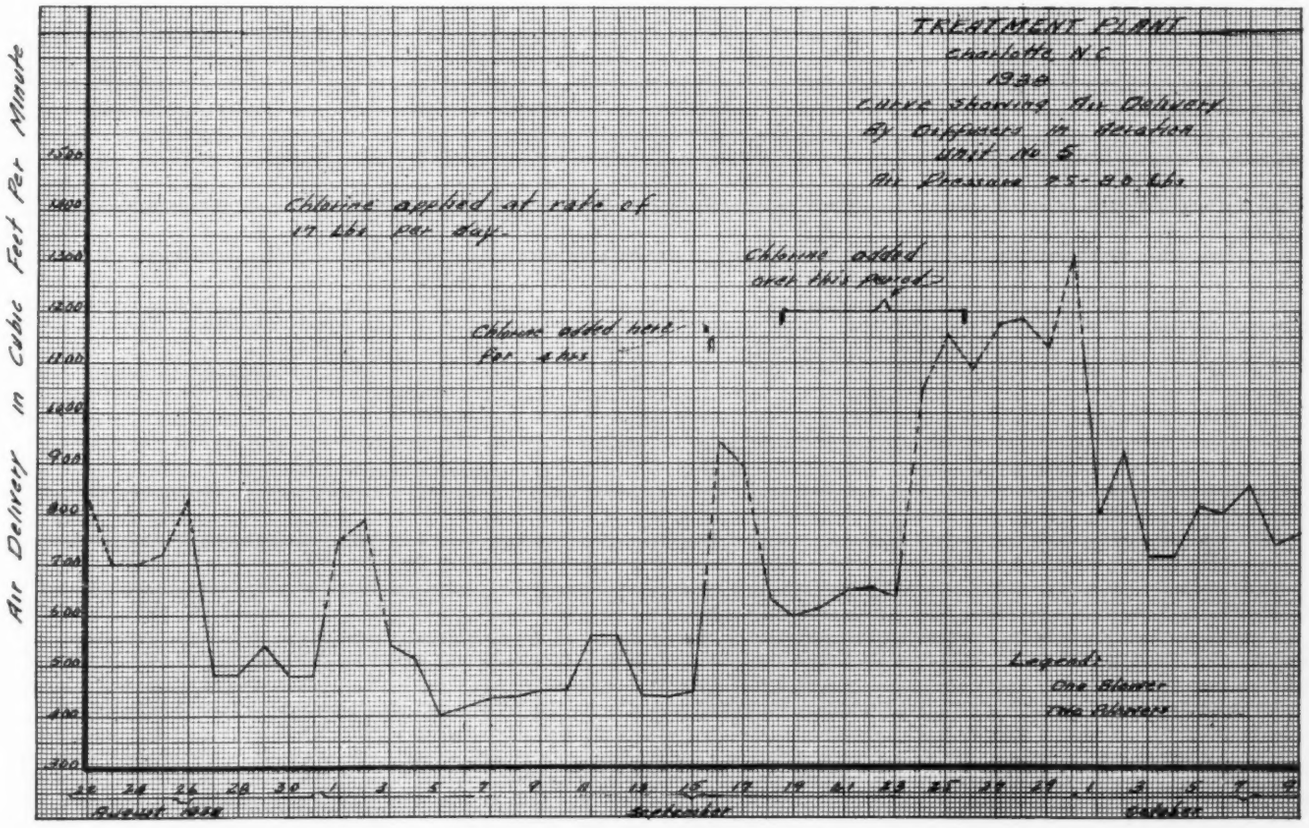

Fig. 1.—Graph Showing Change in Air Delivery Before and After Treatment of Plates With Chlorine Gas, in Situ

THE DOW CHEMICAL COMPANY

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DOW FERRIC CHLORIDE

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FOR SEWAGE COAGULATION

- **Greater removal of suspended solids.**
- **Lower 5-day B.O.D.**
- **Increased flexibility to meet peak loads and low stream flows.**
- **Economical effluent improvement.**
- **Reduction of hydrogen sulphide odors.**

FOR SLUDGE CONDITIONING

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- **Cuts dewatering equipment cost — increases performance.**
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- **Forms a compact, quick settling floc with complete precipitation at any pH value above 5. Retains effectiveness in cold weather.**
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- **In conjunction with lime, removes iron and manganese.**
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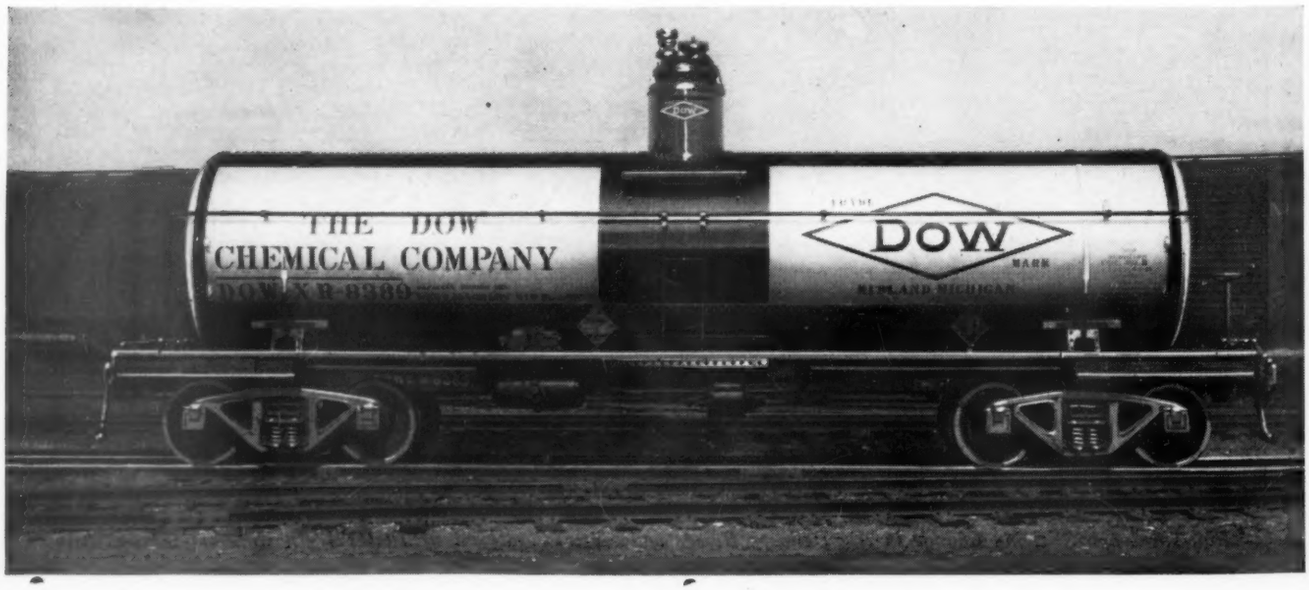
Dow Ferric Chloride 38-45% Solution is shipped in tank cars. Ferric Chloride 60% Crystals are packed in 300 lb. and 500 lb. heavy wooden barrels, permitting storage without deliquescence of the crystals.

Dow Technical Service covering design and operating problems of sewage disposal plants is available upon request to engineers.



A VACUUM FILTER DRESSING RIG

Saves Cloth, Wire and Time

By W. D. SHEETS
Shift Supervisor of Operation
Sewage Treatment Works, Columbus, Ohio

One of the greatest time-consuming operations in connection with sewage sludge dewatering by use of vacuum filters is that of dressing the filters. By "dressing" is meant the removal of the spirally wound holding wire and spent cloth for replacement with new cloth.

Filter cloth in this type of service is subjected to severe operating conditions, resulting in a relatively short life requiring frequent replacement. Conditioning sludge with ferric chloride and lime causes deposition of calcium salts and other insoluble compounds in the interstices of the cloth. Although such choked clothes may be rejuvenated by dry scrubbing or by giving a dilute hydrochloric acid bath in place, (3% acid or less), the fibers eventually break down from the acid and acid insoluble compounds prevent further treatment. Even ferric chloride when used alone has a similar effect, the deposits consisting of iron compounds which are unaffected by the acid bath.

The total filter installation at Columbus consists of four 8 ft. by 12 ft. filters having an area of 300 sq. ft. each. Individual cloths are approximately 13 ft. by 25 ft., a size that is bulky and cumbersome.

When operations were started at Columbus, a wiring rig of 4x4's, such as described in the manufacturers' instructions, was constructed and used with individual cloths for some time. This was extremely heavy and very hard to anchor properly, requiring constant attention to keep it at the correct angle with respect to the filter drum.

An Improved Rig Developed

A study of the situation was made and the following improvements were believed possible by the design of new apparatus:

(1) Storage and handling of a continuous roll of cloth to eliminate from 1 to 2 feet of waste at each change.

(2) To facilitate the removal of the old wire and to assist in the reapplication of *the same* wire.

(3) Maintain the proper tension in the wire when rewinding.

(4) Satisfactorily braced while in use without requiring a release of the anchorage when correcting for direction of wire pull.

(5) Ease of transportation from one filter to another.

A sketch of the proposed apparatus was made and turned over to our machine shop. Requiring approximately 30 man hours to build it, the mechanism was turned out in record time at an exceptionally low cost.

The accompanying photograph shows the wiring rig in position and illustrates the manner in which the cloth is applied to the filter. A single cloth was used in this photograph to show the comparative capacity of the rig when a full bolt is in place.

Not shown in the photograph, or drawing, is a hand-operated lever put to use when rewinding the old wire. This lever guides the wire into position on the reel (center of rig) and prevents pyramiding. Such pyramiding results in subsequent collapse and loss of tension when rewiring. This lever is mounted on the angle iron member seen just above the wire reel. It moves back and forth in a horizontal plane when in use.

Results Attained

With respect to the improvements listed above the corresponding results were as follows:

(1) Cloth is now purchased in sections having a width of 12-ft 8-in. and 152-ft. in length. This length is sufficient for six coverings.

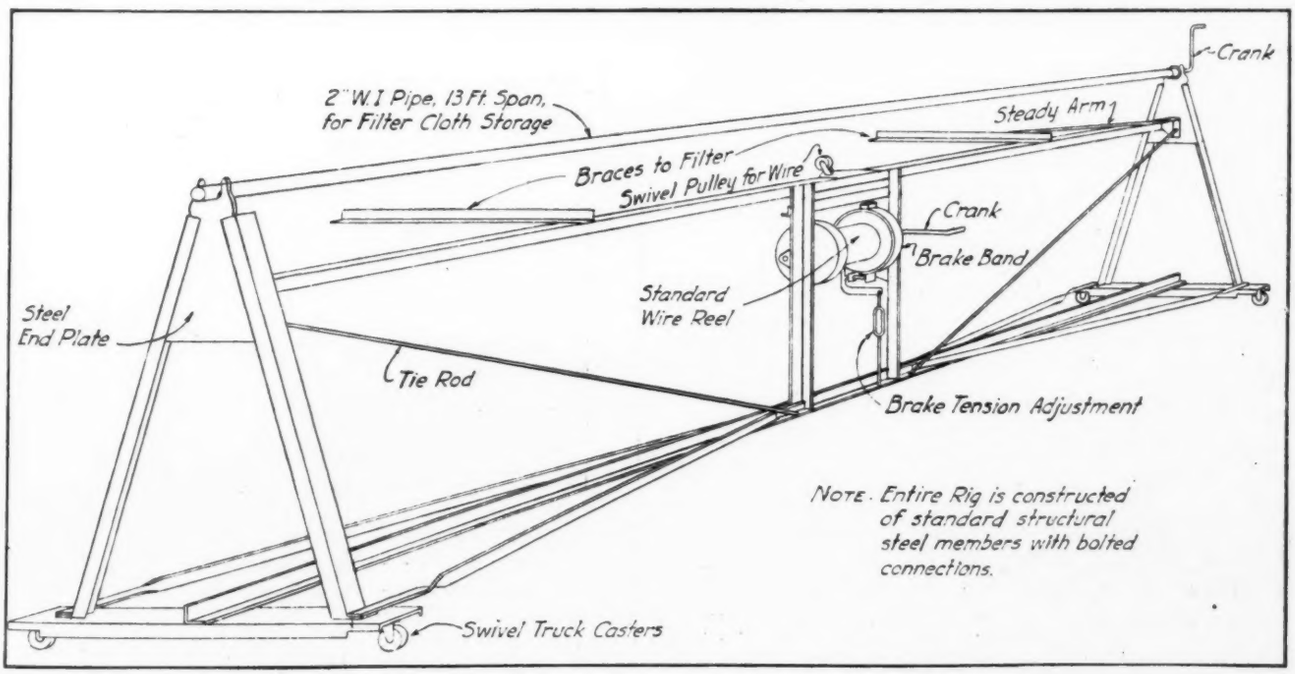
(2) Since the wire used is monel-metal, and subject to deterioration only through wear, its careful removal from the drum and its re-use represents a saving of approximately 1200 feet of wire per re-covering. The only loss is a short section, from the filter drum to the reel on the rig. which is necessary to hold the tension on the entire winding until it has been anchored at the drum.

(3) Any tension desired can be attained through the adjustable brake drum on the reel.

(4) Very rigid bracing resulted, and direction of wire pull is automatically corrected by a swivel pulley directly above the wire reel.

(5) The apparatus can be disengaged, moved to another filter and attached ready for operation in 5 minutes.

This rig is extremely adaptable and has cut the time of dressing from approximately 16 man hours to 6½ man hours per filter. It has enabled the filter operators to change a cloth while attending to their regular operating routine. Several coats of aluminum paint have made it perfectly at home in its present surroundings and it has proved exceptionally satisfactory in all respects.



Sketch Showing Simplicity of Construction of the Columbus Rig
Lightness of weight and swivel casters makes for easy handling. Note wire saving reel at center.

Underpinning & Foundation Co., Inc.

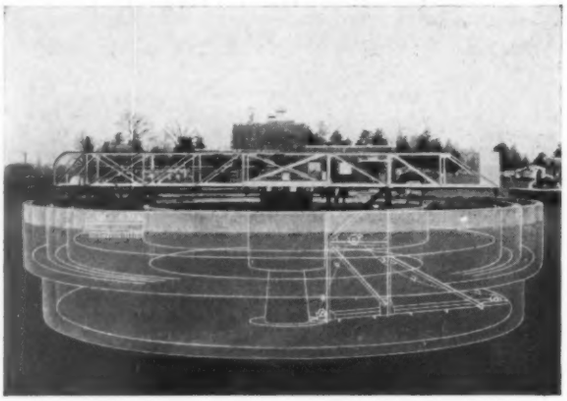
155 East 44th St.
New York, N. Y.

PRODUCTS:

Multi-Zone furnaces for incineration of sewage sludge, screenings and ground garbage.

Dryers—for sewage sludge and industrial products.

"Municipal" Sand Filter for sewage and trade wastes.



1.9 MGD. filter—Somerville, N. J.—for chemically precipitated sewage.

Municipal Sand cleaners are the only filter units that scour the sand and scrub the screen.

Removal of suspended solids by filter 40 to 50%. Filter gives positive control of suspended solids in effluent and sedimentation period can be safely cut down, thereby greatly reducing cost of settling tanks.

In one revolution of the sand cleaner 86% of the trapped solids are removed from the sand. Unless all solids trapped in the sand are removed bacterial growth on sand and screen soon plug the filter.

Installations at:

South River, N. J.
Somerville, N. J.
Raritan, N. J.
Rutherford, N. J.
Sayreville, N. J.

Multi-Zone furnaces embody many improved principles of multiple hearth furnace operation. Positive and economical drying, or complete and odorless destruction of sewage sludge, screenings and ground garbage, effected by means of Multi-Zone furnaces.

Operation is without auxiliary fuel, completely odorless. Furnace divided into separate drying and burning zones with all gases passing through a high temperature zone. Flexible and automatic temperature control throughout. All gases completely deodorized. Residue uniform, inert, non-offensive ash.

Installations at:

Milwaukee, Wis.
Lansing, Mich.
Raritan, N. J.
Rutherford, N. J.
Niagara Falls, N. Y.
Wisconsin Rapids, Wis.

60 TON furnace—Lansing, Mich. — incinerating digested sewage, sludge cake and garbage.

SLUDGE INCINERATION

A Review of Modern Developments and the Status of the Practice

By E. T. KILLAM

Consulting Engr., New York, N. Y.

Developments in treatment plant equipment during recent years have demonstrated the feasibility of treating sewage essentially without nuisance—in, or adjacent to, closely built up areas. The economic advantages of elimination of long interceptors, and the prevention of deterioration of sewage quality prior to treatment by reducing detention time in interceptors, frequently establishes the desirability of constructing plants relatively close to centers of population instead of at remote locations, essential with some of the older types of plants. The increased importance of satisfactory sludge handling under such conditions has, among other factors, stimulated interest in sludge destruction by burning.

Methods of Sludge Drying and Incineration

Methods of drying and incineration of sewage sludge may be summarized as follows:

(A) Drying (For Fertilizer)

- (1) Without Preliminary Dewatering
  - (a) By Spray Dryer, such as at Plainfield, N. J.
- (2) With Preliminary Dewatering on Sand Drying Beds
  - (a) By Rotary Dryers at Grand Rapids, Mich., and Dayton, Ohio
- (3) With Preliminary Dewatering on Vacuum Filters
  - (a) By Rotary Dryers at Milwaukee, Wis.; Pasadena, Calif.; Houston, Texas

(B) Complete Incineration

- (1) After Dewatering on Sand Beds
  - (a) By Incineration in garbage-rubbish type incinerator of conventional design, contemplated or tried at a few plants with no known case of routine operation
- (2) After Dewatering on Vacuum Filters
  - (a) By Multiple Hearth Type Units for drying and incineration in one-step
  - (b) By Flash Dryer and Pulverized Fuel Type Incinerators, including drying followed by optional incineration

(C) Complete Incineration of Screenings

- (1) After Partial Dewatering in Roll Press
  - (a) In Hand Stoked Modified Garbage and Rubbish Type Incinerators, at Los Angeles "Hyperion" plant since 1934, and at Westchester County Sanitary District Plants since 1930
- (2) After Partial Dewatering in Centrifugal Machines
  - (a) At Milwaukee in hand stoked modified garbage and rubbish type incinerators
  - (b) At Milwaukee and Niagara Falls in multiple hearth type mechanically stoked—since 1937.

In addition to the foregoing applications of drying and incineration of sewage sludge and screenings, equipment now available offers a variety of special combinations deserving consideration in certain cases, and depending upon local conditions. Of particular interest are the possibilities in the combined disposal by incineration of garbage, rubbish, and sewage solids.

It is well recognized that the properly designed and well operated garbage and rubbish incinerator of today, will, under normal conditions, produce a substantial volume of excess heat.

There are notable examples of effective utilization of waste heat from garbage incineration in producing steam and power. The production of power, however, creates certain demands which must be considered in design and operation, and economical power production will for some time be limited to plants of substantial size.

An alternate use of such excess heat from garbage incineration (namely, as a means to drive off sufficient moisture from the sewage solids to make the sludge combustible without purchased auxiliary fuel) affords an interesting application of combined disposal.

Incineration and drying of sewage solids has doubtless been retarded due to the recognized item of operating cost, for driving off the moisture in the upper range of moisture content. If heat which would otherwise go up the incinerator stack may be utilized for this purpose, a consequent substantial reduction in operating cost is effected. This saving, combined with other obvious advantages, in many locations, of constructing the sewage disposal and garbage incineration plants at a common site, should make combined wastes incineration worthy of consideration in numerous instances, and the scope of applicability of incineration of sludge will, thereby, be substantially widened.

Inasmuch as the recent installations have been of the multiple hearth type, or the flash dryer and incineration type, these methods will be further discussed in brief.

Multiple Hearth Type Incineration

In 1934 the multiple hearth type incinerator, developed in the mining industry for roasting copper ore, was first applied to the incineration of sewage sludge at Dearborn, Michigan. In this, as in later installations, sludge is partially dewatered on vacuum filters prior to incineration.

The multiple hearth incinerator consists of a refractory lined circular steel jacketed unit, with as many hearths as may be indicated for the specific installation. Rotating plows on each hearth, driven by a vertical hollow air-cooled central shaft, constantly agitate and plow the material during drying and burning. The material drops through staggered openings in each hearth, to the next hearth below, being finally discharged from the bottom hearth in the form of an inert ash.

Multiple hearth installations normally include a blower for producing a supply of cooling air for the hollow shaft and revolving arms, a motor for driving the rabble arms, a rotating motor driven feeder, oil burner installation, and temperature control equipment.

In several cases preheaters have been included in the layout. The economic justification for a preheater, by means of which waste gases are utilized to heat the air supply to approximately 900 degrees F., depends upon the plant size, contemplated daily duration of operating period, and character and moisture of sludge to be burned.

The planned range of temperature at the furnace exit is approximately 1100 to 1300 degrees F. under normal optimum operating conditions.

Beginning with the notable pioneering installation at Dearborn, Michigan, in 1934, numerous installations of the multiple hearth type incinerator have been undertaken. Recent reports indicate that equipment of this type has been, or is being installed, in 21 or more plants at this writing.

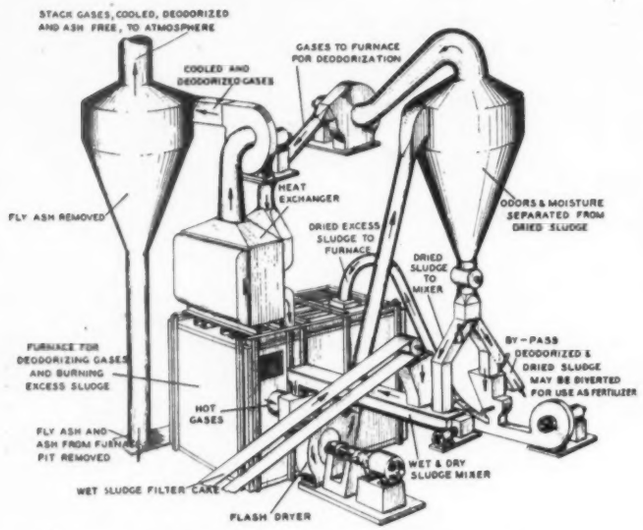
Installations at various plants to date vary in size from a single 9 ft. 3 in. diameter unit of four hearths, to the largest installation at Detroit, where four 22 ft. 3 in. diameter, 12-hearth units have been installed. It thus appears that America's largest Multiple Hearth Furnace installation is approximately seventy times the size of the smallest installation.

The original Dearborn incinerator handles mixed raw chemical and digested Imhoff sludge, the quality of which is indicated by the fact that the long term average volatile content of the cake fed to the incinerator was 46.6 per cent.

Subsequent installations have been in plants which will produce sludge of widely varying characteristics, including the following:

- (a) Raw Primary
- (b) Raw Chemical
- (c) Digested Primary
- (d) Raw Activated
- (e) Digested Activated

Several units have been purchased for incineration of fine screenings and 5 units have been installed with the expressed intention of handling ground garbage along with the sludge.


STACK GASES, COOLED, DEODORIZED AND ASH FREE, TO ATMOSPHERE
GASES TO FURNACE FOR DEODORIZATION
COOLED AND DEODORIZED GASES
HEAT EXCHANGER
FLY ASH REMOVED
ODORS & MOISTURE SEPARATED FROM DRIED SLUDGE
DRIED EXCESS SLUDGE TO FURNACE
DRIED SLUDGE TO MIXER
FURNACE FOR DEODORIZING GASES AND BURNING EXCESS SLUDGE
BY-PASS DEODORIZED & DRIED SLUDGE MAY BE DIVERTED FOR USE AS FERTILIZER
HOT GASES
FLY ASH AND ASH FROM FURNACE PIT REMOVED
WET & DRY SLUDGE MIXER
WET SLUDGE FILTER CAKE
FLASH DRYER

The C. E. Raymond System of Flash Drying and Incineration. (This System Makes Permissible Complete Sludge Incineration or a Partial Diversion for Use as Fertilizer. Another Illustration Shows the Cyclone End of the Raymond System in Service.)

Flash Drying and Incineration

Flash drying and incineration of sewage sludge was first undertaken on a large scale at the West Side Plant of The Chicago Sanitary District in 1933.

This type of equipment involves incineration in two stages—or in other words the drying of the solids to approximately 10 per cent moisture, followed by incineration of the dried material.

The filter cake, with a normal moisture of 75 to 85 per cent, is mechanically mixed with sufficient dried material to develop proper consistency for drying in the flash dryer. Hot gases and this mixture drop into the flash dryer, are violently agitated, and the dried material and vapors are discharged into a cyclone collector. The dried material—approximately 10 per cent moisture—is mechanically divided, a portion being returned to the mixer for blending with the wet filter cake. The balance, or excess, is sent to storage for fertilizer or to a pulverized fuel type of incinerator for destruction, as the case demands. The vent vapors are likewise discharged to the incinerator.

The average design temperature in the dryer is 1100 to 1300 deg. F., and the temperature of the vent vapors varies from approximately 200 to 300 degrees.

The initial installation—at Chicago's West Side Plant, was designed to dry and incinerate raw activated sludge filter cake at 80 to 85 per cent moisture. The rated capacity is 2,000 pounds net dry solids per hour or 8,000 pounds of water evaporation per hour.

Basing the design upon the performance of this unit, equipment was installed at the Calumet Plant of the Chicago Sanitary District and placed in operation in 1935. Three units—each with a capacity of 6,000 pounds net dry solids per hour, or 24,000 pounds of water evaporation per hour, were included. The sludge handled consisted of raw activated filter cake—with small amounts of grit and heavy primary solids from 20 minute detention primary tanks.

In November, 1937, this same type of equipment was placed in service at Neenah-Menasha, Wisconsin, with a capacity of 0.75 tons dry solids per hour, or 3,500 pounds of water evaporation per hour. The sludge at this plant will at times be digested—primary sludge, and at other times will be chemical sludge. A large proportion of paper mill wastes—with high clay content, has at times developed sludge as low as 35 per cent in volatile content.

Similar equipment is now being installed at Buffalo, New York, for incineration of partially digested primary sludge. This plant includes three units each, with a capacity of 5,000 pounds per hour evaporation.

The largest installation of flash drying equipment is in Chicago's notable South West Activated Sludge Plant, where four units—each served by two drying units, with the latter having an evaporation capacity of 20,000 pounds each per hour, are being installed. In this installation power will be generated from combustion of the pulverant dried sludge, with the assistance of auxiliary powdered coal. In this single plant with a total evaporation capacity of 40 tons per hour, combustion engineering has attained a real goal in sewerage practice in America.

The first installation under contract locally, is at Tenafly, N. J., where a small single unit of the drying apparatus, with an evaporation capacity of approximately 0.35 tons per hour, is to be installed, for drying raw activated sludge filter cake and fine screenings, preparatory to the burning of the dried material with garbage and rubbish in open hearth incinerator of conventional design.

Summary

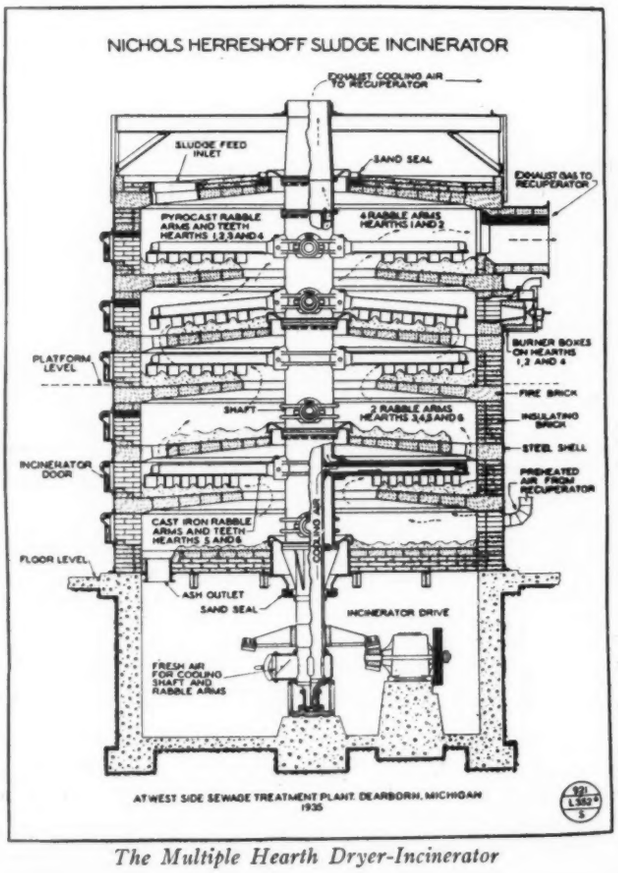
In summary, sludge disposal by drying or incineration has constituted one of the most active phases of development, in the past few years, in the field of sewage treatment.

While operating data and operating costs for a variety of installations will soon be available, it can be safely stated that careful consideration of the local conditions in each municipality will be necessary in order to approach the most economical solution of the problem.

The variables affecting alternate methods of sludge disposal vary no less than the wide range of requirements for degree of sewage treatment. In this way, it would appear that a careful analysis of the problem prior to final selection of the method of sludge disposal, will necessitate thorough consideration of the variables involved.

The characteristics of the sludge and moisture and combustibles content vary widely, depending upon the type of treatment from which the sludge originates. The volatile content of various sludges may vary to as wide a range as from 30 per cent of the total dry solids, to 80 per cent, or even higher. While a heat value of 10,000 B.t.u. per pound of dry volatile matter has frequently been used in computation, additional experience indicates wide variations in B.t.u. content per pound of combustibles.

The demonstrated performance in sludge incineration during the past few years, however, has placed this much needed facility in an important position as a method of sludge disposal. The above variables mentioned will not, it is believed, be of sufficient importance to jeopardize the success of the method, but will affect merely the economic advantages of one method or type of incinerator over another, where incineration is indicated as the preferred method.


NICHOLS HERRESHOFF SLUDGE INCINERATOR
EXHAUST COOLING AIR TO RECUPERATOR
SLUDGE FEED INLET
SAND SEAL
EXHAUST GAS TO RECUPERATOR
PYROCAST RABBLE ARMS AND TEETH HEARTHS 1,2,3 AND 4
4 RABBLE ARMS HEARTHS 1 AND 2
PLATFORM LEVEL
BURNER BOXES ON HEARTHS 1,3 AND 4
FIRE BRICK
SHAFT
2 RABBLE ARMS HEARTHS 3,4,5 AND 6
INSULATING BRICK
STEEL SHELL
INCINERATOR DOOR
PREHEATED AIR FROM RECUPERATOR
CAST IRON RABBLE ARMS AND TEETH HEARTHS 5 AND 6
FLOOR LEVEL
ASH OUTLET SAND SEAL
INCINERATOR DRIVE
FRESH AIR FOR COOLING SHAFT AND RABBLE ARMS
AT WEST SIDE SEWAGE TREATMENT PLANT, DEARBORN, MICHIGAN 1935

The Multiple Hearth Dryer-Incinerator

ENGINEERING DATA

CONVERSION FACTORS FOR ENGINEERS*

The word gallon, used in any conversion factor, designates the U. S. gallon. Likewise, the word ton designates a short ton, 2,000 pounds.

The figures 10^{-1}, 10^{-2}, 10^{-3}, etc., denote 0.1, 0.01, 0.001, etc., respectively.

The figures 10^{1}, 10^{2}, 10^{3}, etc., denote 10, 100, 1000, etc.. respectively.

"Parts Per Million," (designated as p.p.m.), is always by weight. As used in the sanitary field, p.p.m. represents the number of pounds of dry solids contained in one million pounds of water. In this field, one part per million may be expressed as 8.345 pounds of dry solids to one million U. S. gallons of water.

Multiply	By	To Obtain
Acres	43,560	Square feet
"	4047	Square meters
Acre-feet	43,560	Cubic feet
" "	325,851	Gallons
" "	1233.49	Cubic meters
Atmospheres	29.92	Inches of mercury
"	33.90	Feet of water
"	76.0	Cms. of mercury
"	14.70	Lbs./sq. inch
Barrels cement	376	Pounds—cement
Bags or sacks-cement	94	Pounds— "
British Thermal Units	777.5	Foot-lbs.
" " "	3.927×10^{-4}	Horse-power-hrs.
" " "	2.928×10^{-4}	Kilowatt-hrs.
" " "	0.2520	Kilogram-calories
" " "	107.5	Kilogram-meters
B.T.U./min.	12.96	Foot-lbs./sec.
" "	0.02356	Horse-power
" "	0.01757	Kilowatts
Centimeters	0.3937	Inches
Centimeters of mercury	0.01316	Atmospheres
" " "	0.4461	Feet of water
" " "	27.85	Lbs./sq. ft.
" " "	0.1934	Lbs./sq. inch
Centimeters/second	1.969	Feet/min.
" "	0.03281	Feet/sec.
" "	0.6	Meters/min.
Cubic centimeters	3.531×10^{-5}	Cubic feet
" "	6.102×10^{-2}	Cubic inches
" "	2.642×10^{-4}	Gallons
" "	10^{-6}	Cubic meters
" "	10^{-3}	Liters
Cubic feet	7.48052	Gallons
" "	1728	Cubic inches
" "	0.03704	Cubic yards
" "	28.32	Liters
" "	2.832×10^{4}	Cubic cms.
" "	0.02832	Cubic meters
Cubic feet/second	0.646317	Million gals./day
" " "	448.831	Gallons/min.
Cubic inches	16.39	Cubic centimeters
" "	5.787×10^{-4}	Cubic feet
" "	1.639×10^{-5}	Cubic meters
" "	4.329×10^{-3}	Gallons
" "	1.639×10^{-2}	Liters
Cubic meters	35.31	Cubic feet
" "	1.308	Cubic yards
" "	264.2	Gallons
" "	10^{3}	Liters
Cubic yards	27	Cubic feet
" "	46.656	Cubic inches
" "	0.7646	Cubic meters
" "	202.0	Gallons
" "	764.6	Liters
Drams	27.34375	Grains
"	0.0625	Ounces
"	1.771845	Grams
Fathoms	6	Feet
Feet	30.48	Centimeters
"	0.3048	Meters
Feet of water	0.8826	Inches of mercury
" " "	0.4335	Lbs./sq. inch
" " "	62.43	Lbs./sq. ft.
" " "	0.02950	Atmospheres
" " "	304.8	Kgs./sq. meter
Feet/sec.	30.48	Centimeters/sec.
" "	18.29	Meters/min.
Foot-pounds	1.286×10^{-3}	British thermal units
" "	5.050×10^{-7}	Horse-power-hrs.
" "	0.1383	Kilogram-meters
" "	3.766×10^{-7}	Kilowatt-hrs.
Foot-pounds/min.	3.030×10^{-5}	Horse-power
" " "	2.260×10^{-5}	Kilowatts
Gallons	0.1337	Cubic feet
"	231	Cubic inches
"	3785	Cubic centimeters
"	3.785×10^{-3}	Cubic meters
"	3.785	Liters
Gallons, Imperial	1.200095	U. S. gallons
" U. S.	0.83267	Imperial gallons
Gallons water	8.3453	Pounds of water
Gallons/min.	2.228×10^{-3}	Cubic feet/sec.
" "	0.06308	Liters/sec.
" "	8.0208	Cu. ft./hr.
Grains (troy)	1	Grains (avoir.)
"	0.06480	Grams
Grains/U.S. gal.	17.118	Parts/million
" /U.S. gal.	142.86	Lbs./million gal.
" /Imp. gal.	14.254	Parts/million
Grams	15.43	Grains
"	0.03527	Ounces
"	980.7	Dynes
Grams/liter	58.417	Grains/gal.
" "	8.345	Pounds/1000 gals.
" "	1000	Parts/million
Hectares	2.471	Acres
Horse-power	42.44	B.T. Units/min.
" "	550	Foot-lbs./sec.
" "	0.7457	Kilowatts
Horse-power (boiler)	33,479	B.T.U./hr.
" " "	9.803	Kilowatts
Inches	2.540	Centimeters
Inches of mercury	1.133	Feet of water
" " "	0.4912	Lbs./sq. inch
" " "	0.03342	Atmospheres
" " "	345.3	Kgs./sq. meter
Inches of water	0.07355	Inches of mercury
" " "	0.03613	Lbs./sq. inch
Kilograms	2.205	Lbs.
Kilograms-calories/min.	51.43	Foot-pounds/sec.
" " "	0.09351	Horse-power
" "	0.06972	Kilowatts
Kgs./sq. meter	3.281×10^{-3}	Feet of water
" " "	1.422×10^{-3}	Lbs./sq. inch
Kilometers	3281	Feet
"	0.6214	Miles
Kilometers/hr.	0.9113	Feet/sec.
" "	27.78	Centimeters/sec.
Kilowatts	56.92	B.T. Units/min.
"	737.6	Foot-lbs./sec.
"	1.341	Horse-power
"	14.34	Kg.-calories/min.
Liters	0.2642	Gallons
"	61.02	Cubic inches
"	0.03531	Cubic feet
Meters	3.281	Feet
"	39.37	Inches
"	1.094	Yards
Miles	5280	Feet
"	1.609	Kilometers
Miles/min.	88	Feet/sec.
" "	1.609	Kilometers/min.
Milligrams/liter	1	Parts/million
Million gals./day	1.54723	Cubic ft./sec.
Miner's inches	1.5	Cubic ft./min.
Ounces	28.349527	Grams
"	437.5	Grains
"	0.9115	Ounces (troy)
Ounces (fluid)	1.805	Cubic inches
" "	29.57	Cubic cm.
Parts/million	8.345	Lbs./million gal.
" "	0.0584	Grains/U. S. gal.
" "	0.07016	Grains/Imp. gal.
Pounds	16	Ounces
"	7000	Grains
"	453.5924	Grams
"	1.21528	Pounds (troy)

*Selections from a booklet of—"Conversion Factors for Engineers"—distributed by The Dorr Co., New York City.

Multiply	By	To Obtain
Pounds of water	0.01602	Cubic feet
" " "	27.68	Cubic inches
" " "	0.1198	Gallons
Pounds/cubic foot	0.01602	Grams/cubic cm.
" " "	16.02	Kgs./cubic meter
" " "	5.787×10^{-4}	Lbs./cubic inch
Pounds/foot	1.488	Kgs./meter
Pounds/inch	178.6	Grams/cm.
Pounds/sq. foot	0.01602	Feet of water
" " "	4.883	Kgs./sq. meter
Pounds/sq. inch	2.307	Feet of water
" " "	2.036	Inches of mercury
" " "	0.06804	Atmospheres
" " "	703.1	Kgs./sq. meter
Quires	25	Sheets
Reams	500	Sheets
Square centimeters	0.1550	Square inches
" "	1.076×10^{-3}	Square feet
Square feet	144	Square inches
" "	0.09290	Square meters
" "	2.296×10^{-5}	Acres
Square inches	6.452	Square centimeters

Multiply	By	To Obtain
Square kilometers	247.1	Acres
" "	10.76×10^{6}	Square feet
" "	1.196×10^{6}	Square yards
Square meters	10.76	Square feet
" "	1.196	Square yards
Square miles	640	Acres
" "	27.88×10^{6}	Square feet
" "	2.590	Square Kilometers
Square yards	9	Square feet
" "	0.8361	Square meters
" "	2.066×10^{-4}	Acres
Tons (long)	1016	Kilograms
" "	2240	Pounds
" "	1.12000	Tons (short)
Tons (metric)	10^{3}	Kilograms
" "	2205	Pounds
Tons (short)	2000	Pounds
" "	907.18486	Kilograms
Tons of water/24 hrs.	0.16643	Gallons/min.
Watts	0.05692	B.T.Units/min.
"	0.7376	Foot-pounds/sec.
"	1.341×10^{-3}	Horse-power
"	0.01434	Kg.-calories/min.
Yards	0.9144	Meters

Relative Carrying Capacities of Pipe Lines of Equal Smoothness

Prepared by Emil L. Neubling for the Reading Meter Repair Co.

Diameter of Pipes	⅛	¼	⅜	½	¾	1	1¼	1½	2	2½
26										348.81
24										285.55
22										229.20
20									316.23	181.02
18									243.00	139.10
16								371.60	181.02	103.62
15								316.23	154.05	88.18
14							419.80	266.13	129.64	74.21
12							285.55	181.02	88.18	50.48
10						316.23	181.02	114.76	55.90	32.00
9						243.00	139.10	88.18	42.96	24.65
8					371.60	181.02	103.62	65.69	32.00	18.32
7					266.13	129.64	74.21	47.05	22.92	13.12
6					181.02	88.18	50.48	32.00	15.59	8.92
5				316.23	114.76	55.90	32.00	20.29	9.88	5.66
4½				243.00	88.18	42.96	24.65	15.59	7.59	4.35
4			371.60	181.02	65.69	32.00	18.32	11.61	5.66	3.24
3½			266.13	129.64	47.05	22.92	13.12	8.32	4.05	2.32
3			181.02	88.18	32.00	15.59	8.92	5.66	2.76	1.58
2½		316.23	114.76	55.90	20.29	9.88	5.66	3.59	1.75	1.00
2		181.02	65.69	32.00	11.61	5.66	3.24	2.05	1.00	
1½		88.18	32.00	15.59	5.66	2.76	1.58	1.00		
1¼	316.23	55.90	20.29	9.88	3.59	1.75	1.00			
1	181.02	32.00	11.61	5.66	2.05	1.00				
¾	88.18	15.59	5.66	2.05	1.00					
½	32.00	5.66	2.05	1.00						
⅜	15.59	2.76	1.00							
¼	5.66	1.00								
⅛	1.00									

Diameter of Pipes	3	3½	4	4½	5	6	7	8	9	10
48			498.83	371.60	285.55	181.02	123.13	88.18	65.69	50.48
46			448.48	334.09	256.73	162.75	110.70	79.10	59.06	45.38
44			401.31	298.96	229.20	145.63	99.29	70.94	52.85	40.61
42			357.25	243.00	204.50	129.64	88.18	63.15	47.05	36.15
40			316.23	235.57	181.02	114.76	78.06	55.90	41.64	32.00
38		388.41	278.17	207.22	159.23	100.94	68.66	49.17	36.63	28.15
36		339.30	243.00	181.02	139.10	88.18	59.98	42.96	32.00	24.65
34		294.12	210.64	156.92	120.58	76.44	51.99	37.24	27.74	21.32
32		252.76	181.02	134.85	103.62	65.69	44.68	32.00	23.84	18.32
30	316.23	215.10	154.05	114.76	88.18	55.90	38.02	27.23	20.29	15.59
28	266.13	181.02	129.64	96.57	74.21	47.05	32.00	22.92	17.07	13.12
26	221.12	150.41	107.72	80.24	61.66	39.09	26.59	19.04	14.18	10.90
24	181.02	123.13	88.18	65.69	50.48	32.00	21.77	15.59	11.61	8.92
22	145.63	99.29	70.94	52.85	40.61	25.74	17.51	12.54	9.34	7.18
20	114.76	78.06	55.90	41.64	32.00	20.29	13.80	9.88	7.36	5.66
18	88.18	59.98	42.96	32.00	24.65	15.59	10.60	7.59	5.66	4.35
16	65.69	44.68	32.00	23.84	18.32	11.61	7.90	5.66	4.21	3.24
15	55.90	38.02	27.23	20.29	15.59	9.88	6.72	4.81	3.59	2.76
14	47.05	32.00	22.92	17.07	13.12	8.32	5.66	4.05	3.02	2.32
12	32.00	21.77	15.59	11.61	8.92	5.66	3.85	2.76	2.05	1.58
10	20.29	13.80	9.88	7.36	5.66	3.59	2.44	1.75	1.30	1.00
9	15.59	10.60	7.59	5.66	4.35	2.76	1.83	1.34	1.00	
8	11.61	7.90	5.66	4.21	3.24	2.05	1.40	1.00		
7	8.32	5.66	4.05	3.02	2.32	1.47	1.00			
6	5.66	3.85	2.76	2.05	1.58	1.00				
5	3.59	2.44	1.77	1.30	1.00					
4½	2.76	1.83	1.34	1.00						
4	2.05	1.40	1.00							
3½	1.47	1.00								
3	1.00									

Diameter of Pipes	12	14	15	16	18	20	22	24	26	28
48	32.00	21.77	18.32	15.59	11.61	8.92	7.03	5.66	4.63	3.85
46	28.77	19.57	16.47	14.02	10.44	8.02	6.32	5.09	4.16	3.46
44	25.74	17.51	14.71	12.54	9.34	7.18	5.66	4.55	3.73	3.10
42	22.92	15.59	13.12	11.16	8.32	6.39	5.04	4.05	3.32	2.76
40	20.29	13.80	11.61	9.88	7.36	5.66	4.46	3.59	2.94	2.44
38	17.84	12.14	10.21	8.69	6.48	4.98	3.92	3.15	2.58	2.17
36	15.59	10.60	8.92	7.59	5.66	4.35	3.43	2.76	2.26	1.83
34	13.51	9.19	7.74	6.58	4.90	3.77	2.97	2.39	1.96	1.62
32	11.61	7.90	6.65	5.66	4.21	3.24	2.55	2.05	1.68	1.40
30	9.88	6.72	5.66	4.81	3.59	2.76	2.17	1.75	1.43	1.19
28	8.32	5.66	4.76	4.05	3.02	2.32	1.83	1.47	1.20	1.00
26	6.91	4.70	3.96	3.37	2.51	1.93	1.52	1.22	1.00	
24	5.66	3.85	3.24	2.76	2.05	1.58	1.24	1.00		
22	4.55	3.10	2.61	2.22	1.65	1.27	1.00			
20	3.59	2.44	2.05	1.75	1.30	1.00				
18	2.76	1.83	1.58	1.34	1.00					
16	2.05	1.40	1.18	1.00						
15	1.75	1.19	1.00							
14	1.47	1.00								
12	1.00									

Diameter of Pipes	30	32	34	36	38	40	42	44	46	48
48	3.24	2.76	2.37	2.05	1.80	1.58	1.40	1.24	1.11	1.00
46	2.91	2.48	2.13	1.85	1.61	1.42	1.26	1.12	1.00	
44	2.61	2.22	1.91	1.65	1.44	1.27	1.12	1.00		
42	2.32	1.97	1.70	1.47	1.28	1.13	1.00			
40	2.05	1.75	1.50	1.30	1.14	1.00				
38	1.81	1.54	1.32	1.14	1.00					
36	1.58	1.34	1.15	1.00						
34	1.37	1.16	1.00							
32	1.18	1.00								
30	1.00									

The foregoing tables will be found useful in proportioning distribution lines.

Example: To find how many one-half inch pipes can be supplied by a 4-in. line, follow down the ½-in. vertical column to the number opposite 4-in. diameter of the first column, where the number 181.02 is found, which is the number of one-half inch lines that can be supplied by a 4-in. line.

Example: To find how many 12-in. lines can be supplied by a 48-in. line, follow horizontally along the 48-in. diameter of the first column, until you reach the 12-in. vertical column, where the number 32 is found, which is the result desired.

CHART FOR CONVERTING GRAINS PER GALLON TO POUNDS PER MILLION AND THE REVERSE

Courtesy W. Donaldson and Fuller & McClintock, Engineers

POUNDS OF CHEMICAL REQUIRED PER HOUR FOR VARIOUS PUMPAGES & DOSES

PUMPAGE		DOSE - POUNDS PER MILLION GALLONS															
MILLION GALLONS 24 HRS.	THOUSAND GALLONS PER HOUR	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
		DOSE - GRAINS PER GALLON															
		.07	.14	.21	.28	.35	.42	.49	.56	.63	.70	.77	.84	.91	.98	1.05	1.12
1.0	41.7	.417	.833	1.25	1.67	2.08	2.50	2.92	3.33	3.75	4.17	4.58	5.00	5.42	5.83	6.25	6.67
1.5	62.5*	.625	1.25	1.88	2.50	3.13	3.75	4.38	5.00	5.63	6.25	6.88	7.50	8.13	8.75	9.38	10.0
2.0	83.3	.833	1.67	2.50	3.33	4.17	5.00	5.83	6.67	7.50	8.33	9.17	10.0	10.8	11.7	12.5	13.3
2.5	104	1.04	2.08	3.13	4.17	5.21	6.25	7.29	8.33	9.38	10.4	11.5	12.5	13.5	14.6	15.6	16.7
3.0	125*	1.25	2.50	3.75	5.00	6.25	7.50	8.75	10.0	11.3	12.5	13.8	15.0	16.3	17.5	18.8	20.0
3.5	146	1.46	2.92	4.38	5.83	7.29	8.75	10.2	11.7	13.1	14.6	16.0	17.5	19.0	20.4	21.9	23.3
4.0	167	1.67	3.33	5.00	6.67	8.33	10.0	11.7	13.3	15.0	16.7	18.3	20.0	21.7	23.3	25.0	26.7
4.5	187	1.88	3.75	5.63	7.50	9.38	11.3	13.1	15.0	16.9	18.8	20.6	22.5	24.4	26.3	28.1	30.0
5.0	208	2.08	4.17	6.25	8.33	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0	27.1	29.2	31.3	33.3
5.5	229	2.29	4.58	6.88	9.17	11.5	13.8	16.0	18.3	20.6	22.9	25.2	27.5	29.8	32.1	34.4	36.7
6.0	250*	2.50	5.00	7.50	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0
6.5	271	2.71	5.42	8.13	10.8	13.5	16.3	19.0	21.7	24.4	27.1	29.8	32.5	35.2	37.9	40.6	43.3
7.0	292	2.92	5.83	8.75	11.7	14.6	17.5	20.4	23.3	26.3	29.2	32.1	35.0	37.9	40.8	43.8	46.7
7.5	312	3.13	6.25	9.38	12.5	15.6	18.8	21.9	25.0	28.1	31.3	34.4	37.5	40.6	43.8	46.9	50.0
8.0	333	3.33	6.66	10.0	13.3	16.7	20.0	23.3	26.7	30.0	33.3	36.7	40.0	43.3	46.7	50.0	53.3
8.5	354	3.54	7.08	10.6	14.2	17.7	21.3	24.8	28.3	31.9	35.4	39.0	42.5	46.0	49.6	53.1	56.7
9.0	375*	3.75	7.50	11.3	15.0	18.8	22.5	26.3	30.0	33.8	37.5	41.3	45.0	48.8	52.5	56.3	60.0
9.5	396	3.96	7.92	11.9	15.8	19.8	23.8	27.7	31.7	35.6	39.6	43.5	47.5	51.5	55.4	59.4	63.3
10.0	417	4.17	8.33	12.5	16.7	20.8	25.0	29.2	33.3	37.5	41.7	45.8	50.0	54.2	58.3	62.5	66.7
10.5	437	4.38	8.75	13.1	17.5	21.9	26.3	30.6	35.0	39.4	43.8	48.1	52.5	56.9	61.3	65.6	70.0
11.0	458	4.58	9.17	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.8	50.4	55.0	59.6	64.2	68.8	73.3
11.5	479	4.79	9.58	14.4	19.2	24.0	28.8	33.5	38.3	43.1	47.9	52.7	57.5	62.3	67.1	71.9	76.7
12.0	500*	5.00	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0
12.5	521	5.21	10.4	15.6	20.8	26.0	31.3	36.5	41.7	46.9	52.1	57.3	62.5	67.7	72.9	78.1	83.3
13.0	542	5.42	10.8	16.3	21.7	27.1	32.5	37.9	43.3	48.8	54.2	59.6	65.0	70.4	75.8	81.3	86.7
13.5	562	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.6	56.3	61.9	67.5	73.1	78.8	84.4	90.0
14.0	583	5.83	11.7	17.5	23.3	29.2	35.0	40.8	46.7	52.5	58.3	64.2	70.0	75.8	81.7	87.5	93.3
14.5	604	6.04	12.1	18.1	24.2	30.2	36.3	42.3	48.3	54.4	60.4	66.5	72.5	78.5	84.6	90.6	96.7
15.0	625*	6.25	12.5	18.8	25.0	31.3	37.5	43.8	50.0	56.3	62.5	68.8	75.0	81.3	87.5	93.8	100.0

* Exact Values

‡ Courtesy Fuller & McClintock Engineers

1 grain per gallon = 143 pounds per million gallons = 5.95 lbs. per hour for each million gallons
0.70 " " " = 100 " " " " = 4.17 " " " " " "

Example: What weight of Chemical must be fed each hour to give a 70 lb. dose for a pumpage of 8 O.M.G.D. Opposite 8.0 M.G.D. and under 70 find 23.3, which is the correct weight.

Note: It is now becoming modern practice to record and report all chemical dosages in pounds per million (P.M.G.) and thereby have simplification in reporting and recording, rather than using the older scheme involving grains per gallon, parts per million, etc.

NUMBER OF TAPS THAT CAN BE TAKEN FROM PIPE OF VARIOUS SIZES

Diameter of Pipe in Inches	SIZE OF TAPS IN INCHES																							
	¾	1	1¼	1½	2	2½	3	3½	4	4½	5	6	7	8	9	10	12	14	15	16	18	20	22	24
2	11	5	3	2	1																			
2½	20	9	5	3	1	1																		
3	32	15	8	5	2	1	1																	
3½	47	22	13	8	4	2	1	1																
4	65	32	18	11	5	3	2	1	1															
4½	88	42	24	15	7	4	2	1	1	1														
5	114	55	32	20	9	5	3	2	1	1	1													
6	181	88	50	32	15	8	5	3	2	2	1	1												
7	266	129	74	47	22	13	8	5	4	3	2	1	1											
8	371	181	103	65	32	18	11	7	5	4	3	2	1	1										
9		243	139	88	42	24	15	10	7	5	4	2	1	1	1									
10		316	181	114	55	32	20	13	9	7	5	3	2	1	1	1								
12			285	181	88	50	32	21	15	11	8	5	3	2	2	1	1							
14			419	266	129	74	47	32	22	17	13	8	5	4	3	2	1	1						
15				316	154	88	55	38	27	20	15	9	6	4	3	2	1	1	1					
16				371	181	103	65	44	32	23	18	11	7	5	4	3	2	1	1	1				
18					243	139	88	59	42	32	24	15	10	7	5	4	2	1	1	1	1			
20					316	181	114	78	55	41	32	20	13	9	7	5	3	2	2	1	1	1		
22						229	145	99	70	52	40	25	17	12	9	7	4	3	2	2	1	1	1	
24						285	181	123	88	65	50	32	21	15	11	8	5	3	3	2	2	1	1	1

Cylindrical Tank Capacities Per Foot of Depth

(The Cubic Foot Figure Is Also the Area in Each Instance)

Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.	Diam. Ft. In.	Contents Per Ft. Depth Cu. Ft.	Gals.
1	0.785	5.87	9	63.62	475.9	20	314.2	2350	32	804.3	6016	58	2642	19760
1-3	1.227	9.18	9-6	70.88	530.2	20-6	330.1	2469	33	855.3	6398	60	2827	21150
1-6	1.767	13.22	10	78.54	587.5	21	346.4	2591	34	907.9	6792	62	3019	22580
1-9	2.405	17.99	10-6	86.59	647.7	21-6	363.1	2716	35	962.1	7197	64	3217	24060
2	3.142	23.50	11	95.03	710.9	22	380.1	2844	36	1018	7616	66	3421	25590
2-3	3.976	29.74	11-6	103.9	777.0	22-6	397.6	2974	37	1075	8043	68	3632	27170
2-6	4.909	36.72	12	113.1	846.0	23	415.5	3108	38	1134	8483	70	3848	28790
2-9	5.940	44.43	12-6	122.7	918.0	23-6	433.7	3245	39	1195	8940	72	4072	30450
3	7.069	52.88	13	132.7	992.9	24	452.4	3384	40	1257	9404	74	4301	32170
3-3	8.296	62.06	13-6	143.1	1071	24-6	471.4	3527	41	1320	9876	76	4536	33930
3-6	9.621	71.97	14	153.9	1152	25	490.9	3672	42	1385	10360	78	4778	35740
3-9	11.04	82.62	14-6	165.1	1235	25-6	510.7	3820	43	1452	10860	80	5027	37600
4	12.57	94.00	15	176.7	1322	26	530.9	3972	44	1521	11370	82	5281	39500
4-6	15.90	119.0	15-6	188.7	1412	26-6	551.5	4126	45	1590	11900	84	5542	41450
5	19.63	146.9	16	201.1	1504	27	572.6	4283	46	1662	12430	86	5809	43450
5-6	23.76	177.7	16-6	213.8	1600	27-6	594.0	4443	47	1735	12980	88	6082	45490
6	28.27	211.5	17	227.0	1698	28	615.8	4606	48	1810	13540	90	6362	47590
6-6	33.18	248.2	17-6	240.5	1799	28-6	637.9	4772	49	1886	14110	92	6648	49720
7	38.48	287.9	18	254.5	1904	29	660.5	4941	50	1964	14690	94	6940	51920
7-6	44.18	330.5	18-6	268.8	2011	29-6	683.5	5113	52	2124	15890	96	7238	54140
8	50.27	376.0	19	283.5	2121	30	706.9	5288	54	2290	17130	98	7543	56420
8-6	56.75	424.5	19-6	298.6	2234	31	754.8	5646	56	2463	18420	100	7854	58750

WATER PRESSURE

Feet of Head ⇄ Pressure

Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.	Feet Head	Pressure per sq. in.
1	0.43	54	23.39	107	46.34	160	69.31	213	92.20	285	123.45
2	0.86	55	23.82	108	46.78	161	69.74	214	92.69	290	125.62
3	1.30	56	24.26	109	47.21	162	70.17	215	93.13	295	127.78
4	1.73	57	24.69	110	47.64	163	70.61	216	93.56	300	129.95
5	2.16	58	25.12	111	48.08	164	71.04	217	92.99	305	132.12
6	2 59	59	25.55	112	48.51	165	71.47	218	94.43	310	134.28
7	3.03	60	25.99	113	48.94	166	71.91	219	94.86	315	136.46
8	3.46	61	26.42	114	49.38	167	72.34	220	95.30	320	138.62
9	3.89	62	26.85	115	49.81	168	72.77	221	95.73	325	140.79
10	4.33	63	27.29	116	50.24	169	73.20	222	96.16	330	142.95
11	4.76	64	27.72	117	50.68	170	73.64	223	96.60	335	145.12
12	5.20	65	28.15	118	51.11	171	74.07	224	97.03	340	147.28
13	5.63	66	28.58	119	51.54	172	74.50	225	97.46	345	149.45
14	6.06	67	29.02	120	51.98	173	74.94	226	97.90	350	151.61
15	6.49	68	29.45	121	52.41	174	75.37	227	98.33	355	153.78
16	6.93	69	29.88	122	52.84	175	75.80	228	98.76	360	155.94
17	7.36	70	30.32	123	53.28	176	76.23	229	99.20	365	158.10
18	7.79	71	30.75	124	53.71	177	76.67	230	99.63	370	160.27
19	8 22	72	31.18	125	54.15	178	77.10	231	100.0	375	162.45
20	8.66	73	31.62	126	54.58	179	77.53	232	100.49	380	164.61
21	9.09	74	32.05	127	55.01	180	77.97	233	100.93	385	166.78
22	9.53	75	32.48	128	55.44	181	78.40	234	101.36	390	168.94
23	9.96	76	32.92	129	55.88	182	78.84	235	101.70	395	171.11
24	10.39	77	33.35	130	56.31	183	79.27	236	102.23	400	173.27
25	10.82	78	33.78	131	56.74	184	79.70	237	102.66	425	184.10
26	11.26	79	34.21	132	57.18	185	80.14	238	103.09	450	195.0
27	11.69	80	34.65	133	57.61	186	80.57	239	103.53	475	205.77
28	12.12	81	35.08	134	58.04	187	81.0	240	103.96	500	216.58
29	12.55	82	35.52	135	58.48	188	81.43	241	104.39	525	227.42
30	12.99	83	35.95	136	58.91	189	81.87	242	104.83	550	238.25
31	13 42	84	36.39	137	59.34	190	82.30	243	105.26	575	249.09
32	13.86	85	36.82	138	59.77	191	82.73	244	105.69	600	259.90
33	14.29	86	37.25	139	60.21	192	83.17	245	106.13	625	270.73
34	14.72	87	37.68	140	60.64	193	83.60	246	106.56	650	281.56
35	15.16	88	38.12	141	61.07	194	84.03	247	106.99	675	292.40
36	15.59	89	38.55	142	61.51	195	84 47	248	107.43	700	303.22
37	16.02	90	39.08	143	61.94	196	84.90	249	107.86	725	314.05
38	16.45	91	39.42	144	62.37	197	85 33	250	108.29	750	324.88
39	16.89	92	39.85	145	62.81	198	85.76	251	108.73	775	335.72
40	17.32	93	40.28	146	63.24	199	86.20	252	109.16	800	346.54
41	17.75	94	40.72	147	63.67	200	86.63	253	109.59	825	357.37
42	18.19	95	41.15	148	64.10	201	87 07	254	110.03	850	368.20
43	18.62	96	41.58	149	64.54	202	87.50	255	110.46	875	379.03
44	19.05	97	42.01	150	64.97	203	87.93	256	110.89	900	389.86
45	19.49	98	42.45	151	65.40	204	88.36	257	111.32	925	400.70
46	19.92	99	42.88	152	65.84	205	88.80	258	111.76	950	411.54
47	20.35	100	43.31	153	66.27	206	89.21	259	112.19	975	422.35
48	20.79	101	43.75	154	66.70	207	89.66	260	112.62	1000	433.18
49	21.22	102	44.18	155	67.14	208	90.10	261	113.06	1500	649.7
50	21.65	103	44.61	156	67.57	209	90.53	262	113.49	2000	866.3
51	22.09	104	45.05	157	68.0	210	90.96	270	116.96	3000	1299.5
52	22.52	105	45.48	158	68.43	211	91.39	275	119.12		
53	22.95	106	45.91	159	68 87	212	91.83	280	121.29		

Based on a density of 62.355 pounds per cu. ft. for water at 62°F.

Theoretical Horsepower

$$\text{Water Horsepower} = \frac{\text{G. P. M.} \times \text{Head in Feet}}{3960}$$

HEAD IN FEET

Gallons per minute — Ft.	10	15	20	25	30	35	40	45	50	60	75	90	100
10	03	04	05	06	08	09	10	.11	.13	.15	.19	.23	.25
15	.04	.06	.08	.09	.11	.13	.15	.17	.19	.23	.28	.34	.38
20	.05	.08	.10	.13	.15	.18	.20	.22	.25	.30	.38	.45	.50
25	.06	.10	.13	.16	.19	.22	.25	.28	.32	.38	'47	.57	.68
30	.08	.11	.15	.19	.23	.26	.30	.34	.38	.45	.57	.68	.75
35	.09	.13	.18	.22	26	.31	.35	.40	.44	.53	.66	.80	.88
40	.10	.15	.20	.25	.30	.35	.40	.45	.50	.61	.76	.91	1.01
45	.11	.17	.23	.28	34	.40	.45	.51	.57	.68	.85	1.02	1.14
50	.13	.19	.25	.32	.38	.44	.50	.57	.63	.76	.95	1.14	1.26
60	.15	.23	.30	.38	.46	.53	.61	.68	.76	.91	1.14	1.36	1.52
75	.19	.28	.38	.47	.57	.66	.76	85	.95	1.14	1.42	1.70	1.89
90	.23	.34	.45	.57	.68	.80	.91	1.02	1.14	1.36	1.70	2.04	2.27
100	.25	.38	.50	63	.76	.88	1 01	1.14	1.26	1 51	1.89	2.27	2.52
125	.32	.47	.63	.79	.97	1.10	1.26	1.42	1.58	1.89	1.37	2.84	3.16
150	.38	.57	.76	.95	1 14	1.32	1.52	1.70	1.89	2.27	2.84	3.41	3.79
175	.44	.66	.88	1.10	1.32	1.54	1.78	1.99	2.21	2.65	3.31	3.98	4.42
200	.50	.76	1 01	1.26	1.52	1.77	2.02	2.27	2.52	3 03	3.79	4.54	5.05
250	.63	.95	1.26	1.58	1.90	2.20	2.52	2.84	3.16	3.79	4 73	5.68	6.31
300	.76	1.14	1.51	1.90	2.27	2.65	3.03	3.41	3.79	4.54	5.68	6.82	7.58
350	.88	1.33	1.77	2.21	2.65	3.09	3.54	3.98	4.42	5 30	6.62	7.95	8.84
400	1.01	1 52	2.02	2.52	3.03	3.53	4.04	4.55	5.05	6.06	7.57	9 09	10.10
500	1.26	1.90	2.52	3.16	3 78	4.42	5.05	5.69	6 31	7 58	9.47	11.36	12.63
550	1.39	2.08	2.78	3.47	4.17	4.86	5 56	6.26	6.94	8.33	10.42	12.50	13.89
600	1.52	2.28	3.03	3.79	4.55	5.30	6 06	6.82	7.58	9.09	11.36	13.64	15.15
650	1.64	2.47	3.28	4.10	4.93	5.75	6.56	7 39	8.21	9.85	12.31	14.77	16.41
700	1.77	2.65	3.54	4.42	5.30	6.19	7.07	7.96	8.84	10.60	13.26	15.91	17.68
750	1.89	2.85	3.79	4.74	5.68	6 63	7 58	8.53	9.47	11.36	14.20	17.04	18.94
800	2.02	3.04	4.04	5.05	6.06	7.07	8.08	9.10	10 10	12.12	15.15	18.18	20.20
850	2.15	3.23	4 29	5.37	6.44	7.51	8.58	9.67	10.73	12.87	16.10	19.32	21.46
900	2.27	3.42	4.54	5.68	6.82	7.95	9.09	10.24	11.36	13 63	17.04	20.45	22.73
950	2.40	3.60	4 80	6.00	7.20	8.40	9.60	10.80	11.99	14.39	17.99	21.59	23.99
1000	2.52	3.79	5.05	6.31	7.58	8.84	10.10	11.36	12.63	15 15	18.94	22.73	25.25
2000	5.05	7.57	10 10	12.63	15.15	17.67	20.20	22.72	25.25	30.30	37.87	45.45	50.50
3000	7.57	11.37	15.15	18.94	22.72	26.51	30.30	34.09	37.88	45.45	56.81	68.18	75.75
4000	10.10	15.16	20.20	25.25	30.30	35.35	40 40	45.45	50.50	60.60	75.75	90.90	101.01

NOTE:—to get the BRAKE HORSEPOWER required by the pump use the following formula:—

$$\text{Brake Horsepower} = \frac{\text{G. P. M. x Head in Feet}}{\text{3960 x Effy. of the pump}}$$

AREAS OF CIRCLES—SQUARES—SQUARE ROOTS

(Also Fractions to Decimal Equivalent.)

No. N Fraction	Decimal	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)	No. N	N^2	$\sqrt{N}$	Area Circle (N = Diam.)
1/16	.0625	.0039	.2500	.0031	10	100	3.162	78.54	76	5776	8.718	4536.5	142	20164	11.92	15837
1/8	.125	.0156	.3536	.0125	11	121	3.317	95.03	77	5929	8.775	4656.6	143	20449	11.96	16061
3/16	.1875	.0352	.4330	.0276	12	144	3.464	113.1	78	6084	8.832	4778.4	144	20736	12.00	16286
1/4	.25	.0625	.5000	.0491	13	169	3.606	132.7	79	6241	8.888	4901.7	145	21025	12.04	16583
5/16	.3125	.0977	.5590	.0767	14	196	3.742	153.9	80	6400	8.944	5026.5	146	21316	12.08	16742
3/8	.375	.1406	.6124	.1105	15	225	3.873	176.7	81	6561	9.000	5153.0	147	21609	12.12	16972
7/16	.4375	.1914	.6614	.1503	16	256	4.000	201.1	82	6724	9.055	5281.0	148	21904	12.17	17203
1/2	.50	.2500	.7071	.1964	17	289	4.123	227.0	83	6889	9.110	5410.6	149	22201	12.22	17437
9/16	.5625	.3164	.7500	.2485	18	324	4.243	254.5	84	7056	9.165	5541.8	150	22500	12.25	17671
5/8	.625	.3906	.7906	.3068	19	361	4.359	283.5	85	7225	9.220	5674.5	151	22801	12.29	17908
11/16	.6875	.4727	.8297	.3712	20	400	4.472	314.2	86	7396	9.274	5808.8	152	23104	12.33	18146
3/4	.75	.5625	.8660	.4418	21	441	4.583	346.4	87	7569	9.327	5944.7	153	23409	12.37	18385
13/16	.8125	.6602	.9014	.5185	22	484	4.690	380.1	88	7744	9.381	6082.1	154	23716	12.41	18627
7/8	.875	.7656	.9354	.6013	23	529	4.796	415.5	89	7921	9.434	6221.1	155	24025	12.45	18869
15/16	.9375	.8789	.9683	.6903	24	576	4.899	452.4	90	8100	9.487	6361.7	156	24336	12.49	19113
1	1.	1.000	1.000	.7854	25	625	5.000	490.9	91	8281	9.539	6503.9	157	24649	12.53	19359
1 1/16	1.125	1.266	1.061	.9940	26	676	5.099	530.9	92	8464	9.592	6647.6	158	24964	12.57	19607
1 1/4	1.25	1.563	1.118	1.227	27	729	5.196	572.6	93	8649	9.644	6792.9	159	25281	12.61	19856
1 3/8	1.375	1.891	1.175	1.485	28	784	5.292	615.8	94	8836	9.695	6939.8	160	25600	12.65	20106
1 1/2	1.50	2.250	1.225	1.767	29	841	5.385	660.5	95	9025	9.747	7088.2	161	25921	12.69	20358
1 5/8	1.625	2.641	1.275	2.074	30	900	5.477	706.9	96	9216	9.798	7238.2	162	26244	12.73	20613
1 3/4	1.75	3.063	1.323	2.405	31	961	5.568	754.8	97	9409	9.849	7389.8	163	26569	12.77	20867
1 7/8	1.875	3.516	1.369	2.761	32	1024	5.657	804.2	98	9604	9.900	7543.0	164	26896	12.81	21124
2	2.	4.000	1.414	3.142	33	1089	5.745	855.3	99	9801	9.950	7697.7	165	27225	12.85	21382
2 1/8	2.125	4.516	1.458	3.547	34	1156	5.831	907.9	100	10000	10.00	7854.0	166	27556	12.88	21642
2 1/4	2.25	5.063	1.500	3.976	35	1225	5.916	962.1	101	10201	10.05	8011.9	167	27889	12.92	21904
2 3/8	2.375	5.641	1.541	4.430	36	1296	6.000	1017.9	102	10404	10.10	8171.3	168	28224	12.96	22168
2 1/2	2.50	6.250	1.581	4.909	37	1369	6.083	1075.2	103	10609	10.15	8332.3	169	28561	13.00	22432
2 5/8	2.625	6.891	1.620	5.412	38	1444	6.164	1134.1	104	10816	10.20	8494.9	170	28900	13.04	22698
2 3/4	2.75	7.563	1.658	5.940	39	1521	6.245	1194.6	105	11025	10.25	8659.0	171	29241	13.08	22966
2 7/8	2.875	8.266	1.696	6.492	40	1600	6.325	1256.7	106	11236	10.30	8824.7	172	29584	13.11	23235
3	3.	9.000	1.732	7.069	41	1681	6.403	1320.3	107	11449	10.34	8992.0	173	29929	13.15	23506
3 1/8	3.125	9.766	1.768	7.670	42	1764	6.481	1385.4	108	11664	10.39	9160.9	174	30276	13.19	23779
3 1/4	3.25	10.56	1.803	8.296	43	1849	6.557	1452.2	109	11881	10.44	9331.3	175	30625	13.23	24053
3 3/8	3.375	11.39	1.837	8.946	44	1936	6.633	1520.5	110	12100	10.49	9503.3	176	30976	13.27	24328
3 1/2	3.50	12.25	1.871	9.621	45	2025	6.708	1590.4	111	12321	10.54	9676.9	177	31329	13.30	24606
3 5/8	3.625	13.14	1.904	10.32	46	2116	6.782	1661.9	112	12544	10.58	9852.0	178	31684	13.34	24885
3 3/4	3.75	14.06	1.937	11.04	47	2209	6.856	1734.9	113	12769	10.63	10029	179	32041	13.38	25165
3 7/8	3.875	15.02	1.969	11.79	48	2304	6.928	1809.6	114	12996	10.68	10207	180	32400	13.42	25447
4	4.	16.00	2.000	12.57	49	2401	7.000	1885.7	115	13225	10.72	10387	181	32761	13.45	25730
4 1/8	4.125	17.02	2.031	13.36	50	2500	7.071	1936.5	116	13456	10.77	10568	182	33124	13.49	26016
4 1/4	4.25	18.06	2.062	14.19	51	2601	7.141	2042.8	117	13689	10.82	10751	183	33489	13.53	26302
4 3/8	4.375	19.14	2.092	15.03	52	2704	7.211	2123.7	118	13924	10.86	10936	184	33856	13.56	26590
4 1/2	4.50	20.25	2.121	15.90	53	2809	7.280	2206.2	119	14161	10.91	11122	185	34225	13.60	26880
4 5/8	4.625	21.39	2.151	16.80	54	2916	7.349	2290.2	120	14400	10.95	11310	186	34596	13.64	27172
4 3/4	4.73	22.56	2.180	17.72	55	3025	7.416	2375.8	121	14641	11.00	11499	187	34969	13.67	27465
4 7/8	4.875	23.77	2.208	18.67	56	3136	7.483	2463.0	122	14884	11.05	11690	188	35344	13.71	27759
5	5.00	25.00	2.236	19.64	57	3249	7.500	2551.8	123	15129	11.09	11882	189	35721	13.75	28055
5 1/4	5.25	27.56	2.291	21.65	58	3364	7.616	2642.1	124	15376	11.14	12076	190	36100	13.78	28353
5 1/2	5.50	30.25	2.345	23.76	59	3481	7.681	2734.0	125	15625	11.18	12272	191	36481	13.82	28652
5 3/4	5.75	33.06	2.398	25.97	60	3600	7.746	2827.4	126	15876	11.23	12469	192	36864	13.86	28953
6	6.	36.00	2.450	28.27	61	3721	7.810	2922.5	127	16129	11.27	12668	193	37249	13.89	29255
6 1/4	6.25	39.06	2.500	30.68	62	3844	7.874	3019.1	128	16384	11.31	12868	194	37636	13.93	29559
6 1/2	6.50	42.25	2.550	33.18	63	3969	7.937	3117.2	129	16641	11.36	13070	195	38025	13.96	29865
6 3/4	6.75	45.56	2.598	35.78	64	4096	8.000	3217.0	130	16900	11.40	13273	196	38416	14.00	30172
7	7.	49.00	2.646	38.48	65	4225	8.062	3318.3	131	17161	11.45	13478	197	38809	14.04	30481
7 1/4	7.25	52.56	2.693	41.28	66	4356	8.124	3421.2	132	17424	11.49	13685	198	39204	14.07	30791
7 1/2	7.50	56.25	2.739	44.18	67	4489	8.185	3525.7	133	17689	11.53	13893	199	39601	14.11	31103
7 3/4	7.75	60.06	2.784	47.17	68	4624	8.246	3631.7	134	17956	11.58	14103	200	40000	14.14	31416
8	8.00	64.00	2.828	50.27	69	4761	8.307	3739.3	135	18225	11.62	14314	...	.....	....	.....
8 1/4	8.25	68.06	2.872	53.46	70	4900	8.367	3848.5	136	18496	11.66	14527	...	.....	....	.....
8 1/2	8.50	72.25	2.916	56.75	71	5041	8.426	3959.2	137	18769	11.70	14741	...	.....	....	.....
8 3/4	8.75	76.56	2.958	60.13	72	5184	8.485	4071.5	138	19044	11.75	14957	...	.....	....	.....
9	9.00	81.00	3.000	63.62	73	5329	8.544	4185.4	139	19321	11.79	15175	...	.....	....	.....
9 1/4	9.25	85.56	3.041	67.20	74	5476	8.602	4300.8	140	19600	11.83	15394	...	.....	....	.....
9 1/2	9.50	90.25	3.082	70.88	75	5625	8.660	4417.9	141	19881	11.87	15615				
9 3/4	9.75	95.06	3.123	74.66												

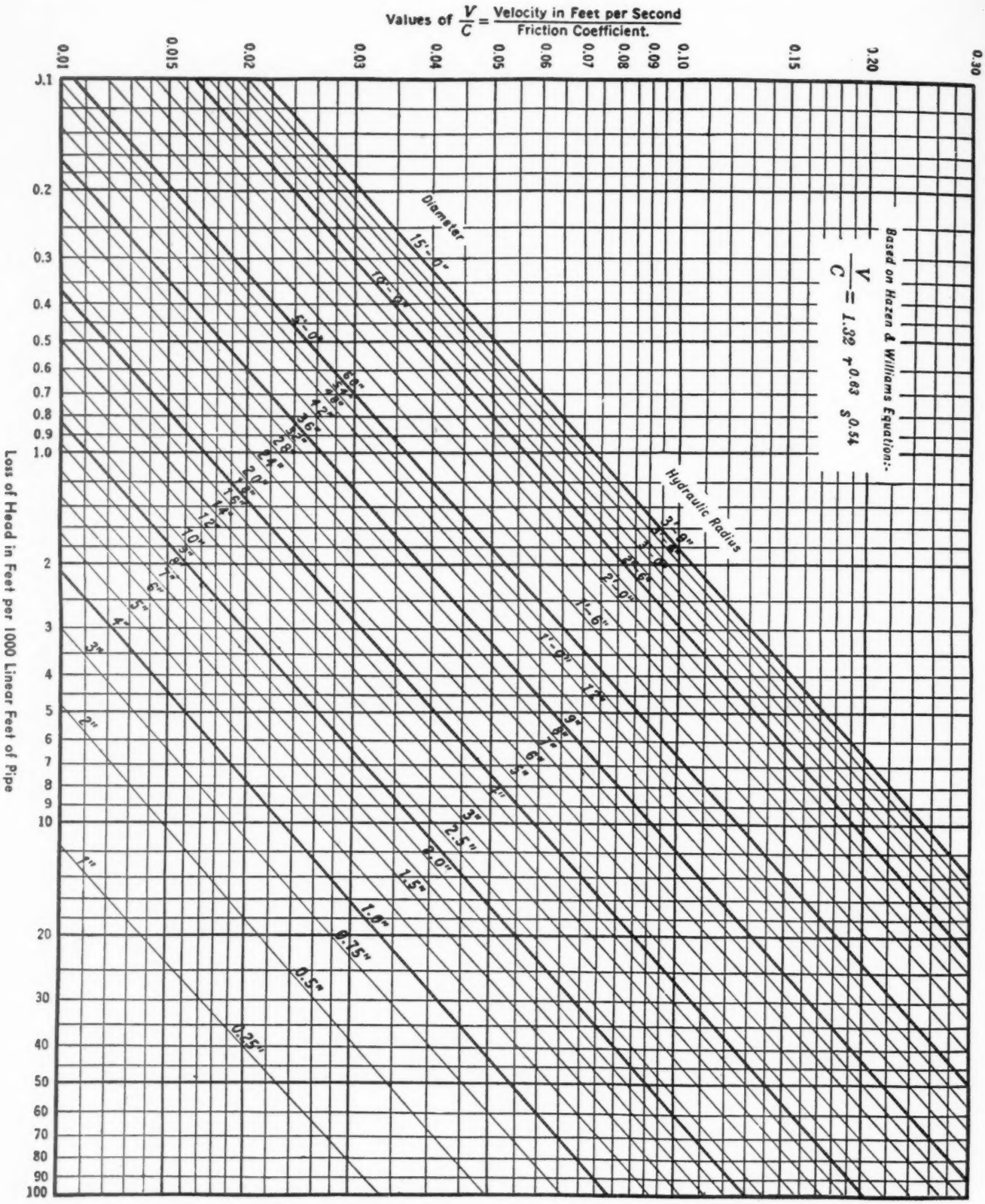


CHART OF LOSS OF HEAD IN FEET PER 1000 FT. OF PIPE

From "Hydro-Electric Handbook"—John Wiley & Sons

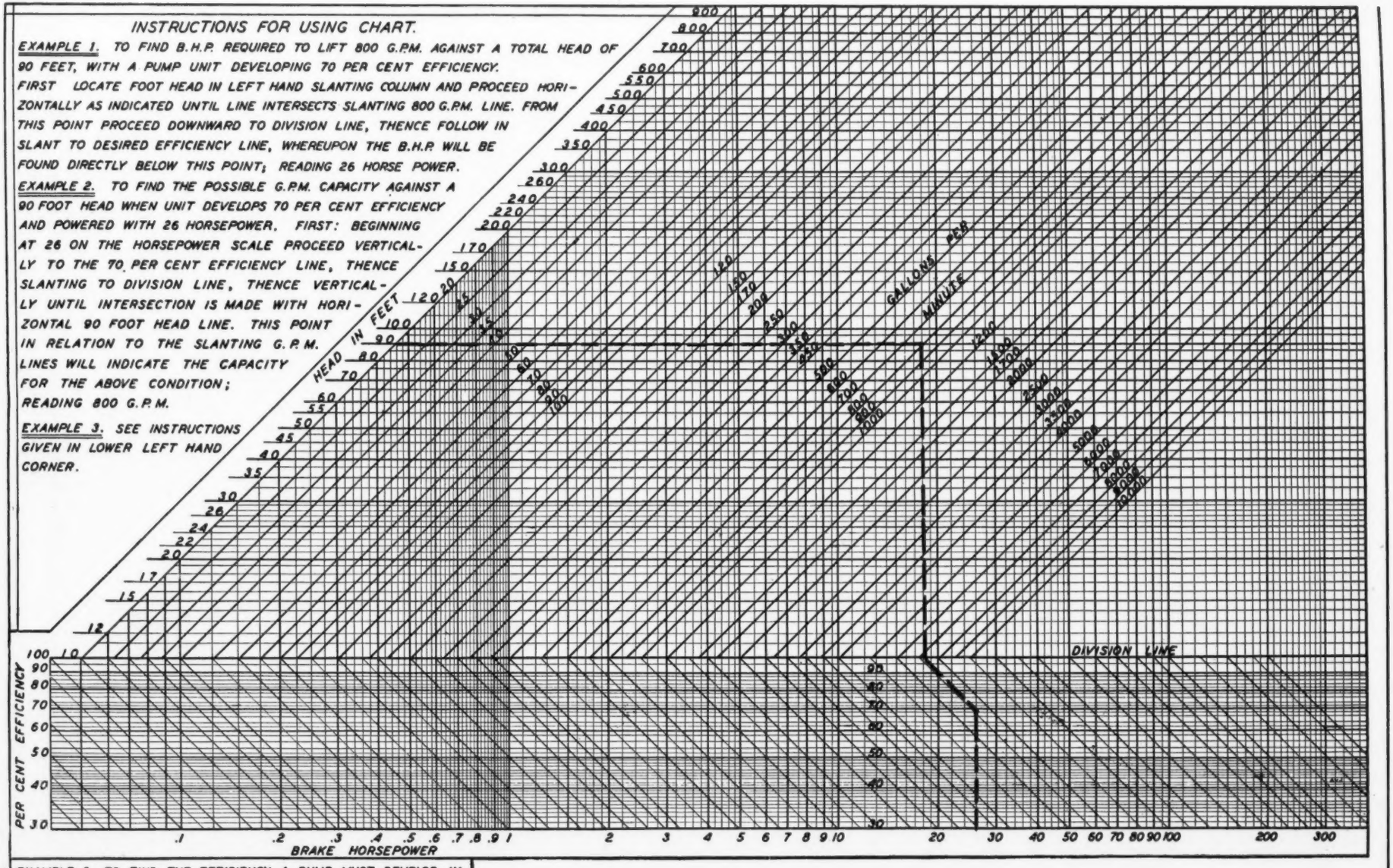

INSTRUCTIONS FOR USING CHART.
EXAMPLE 1. TO FIND B.H.P. REQUIRED TO LIFT 800 G.P.M. AGAINST A TOTAL HEAD OF 90 FEET, WITH A PUMP UNIT DEVELOPING 70 PER CENT EFFICIENCY. FIRST LOCATE FOOT HEAD IN LEFT HAND SLANTING COLUMN AND PROCEED HORIZONTALLY AS INDICATED UNTIL LINE INTERSECTS SLANTING 800 G.P.M. LINE. FROM THIS POINT PROCEED DOWNWARD TO DIVISION LINE, THENCE FOLLOW IN SLANT TO DESIRED EFFICIENCY LINE, WHEREUPON THE B.H.P. WILL BE FOUND DIRECTLY BELOW THIS POINT; READING 26 HORSE POWER.
EXAMPLE 2. TO FIND THE POSSIBLE G.P.M. CAPACITY AGAINST A 90 FOOT HEAD WHEN UNIT DEVELOPS 70 PER CENT EFFICIENCY AND POWERED WITH 26 HORSEPOWER. FIRST: BEGINNING AT 26 ON THE HORSEPOWER SCALE PROCEED VERTICALLY TO THE 70 PER CENT EFFICIENCY LINE, THENCE SLANTING TO DIVISION LINE, THENCE VERTICALLY UNTIL INTERSECTION IS MADE WITH HORIZONTAL 90 FOOT HEAD LINE. THIS POINT IN RELATION TO THE SLANTING G.P.M. LINES WILL INDICATE THE CAPACITY FOR THE ABOVE CONDITION; READING 800 G.P.M.
EXAMPLE 3. SEE INSTRUCTIONS GIVEN IN LOWER LEFT HAND CORNER.
HEAD IN FEET
GALLONS PER MINUTE
DIVISION LINE
PER CENT EFFICIENCY
BRAKE HORSEPOWER
EXAMPLE 3. TO FIND THE EFFICIENCY A PUMP MUST DEVELOP IN ORDER TO DELIVER 800 G.P.M. AGAINST A 90 FOOT HEAD WITH 26 HORSEPOWER. PROCEED AS IN EXAMPLE 1 TO DIVISION LINE, THEN SLANTWISE UNTIL INTERSECTION IS MADE WITH THE VERTICAL 26 HORSEPOWER LINE. THIS POINT WILL LOCATE THE HORIZONTAL EFFICIENCY LINE; READING 70 PER CENT.

Chart for Determining Head, Capacity, Efficiency, Horse Power With Any Three Conditions Known

(From the Peerless Pump Bulletin)

pH CONVERSION CHART

NOTE: *This chart has an especial usefulness in determining free carbon-dioxide content of waters without making the tedious and frequently inaccurate CO_2 titration. Alkalinity and pH readings are more easily and accurately made. To find CO_2 content —Locate pH value diagonal; follow it to intersection with alkalinity value vertical. The horizontal line passing through this same point reveals the correct free CO_2 content. Courtesy Nicholas S. Hill Associates, New York City.*

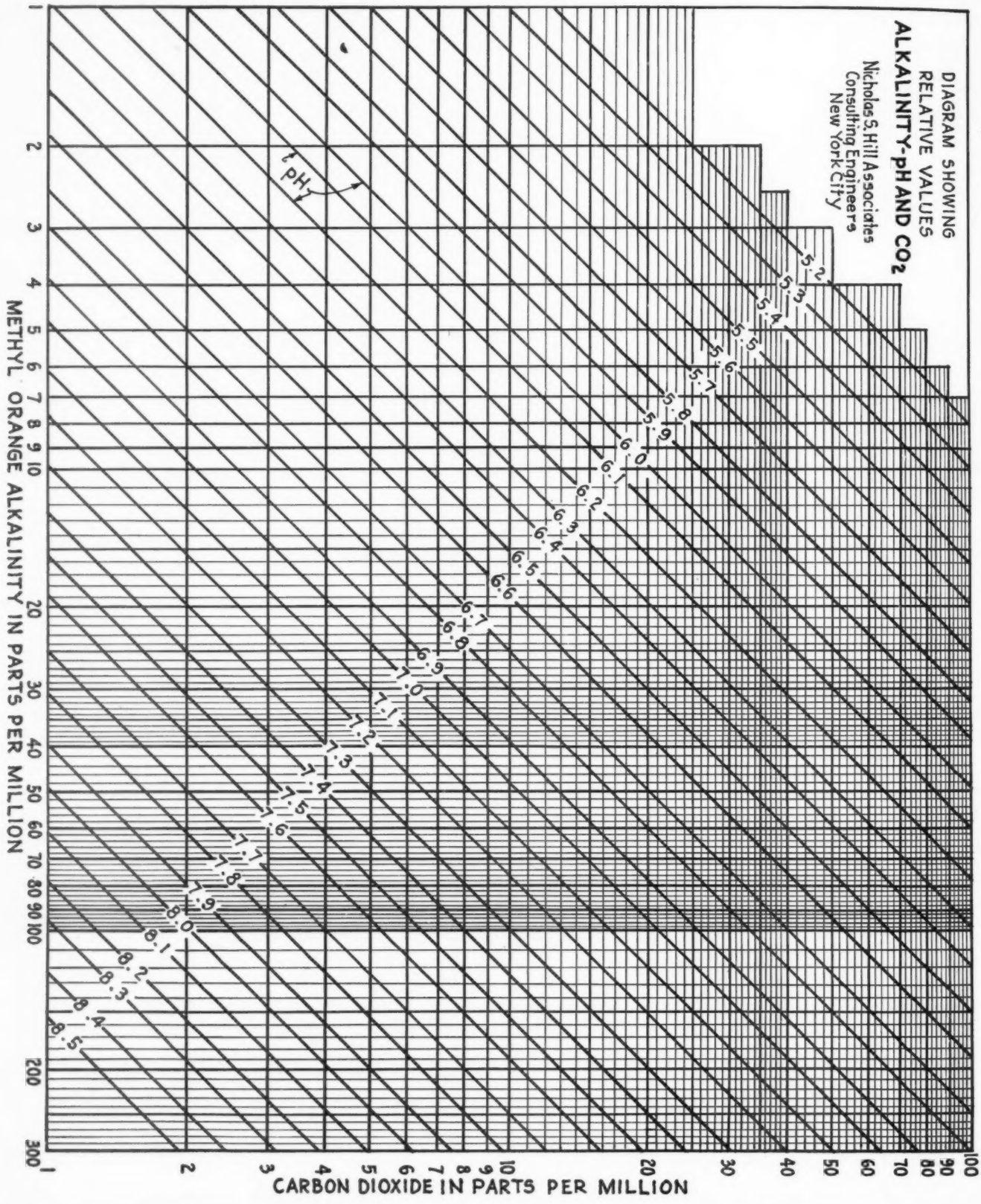
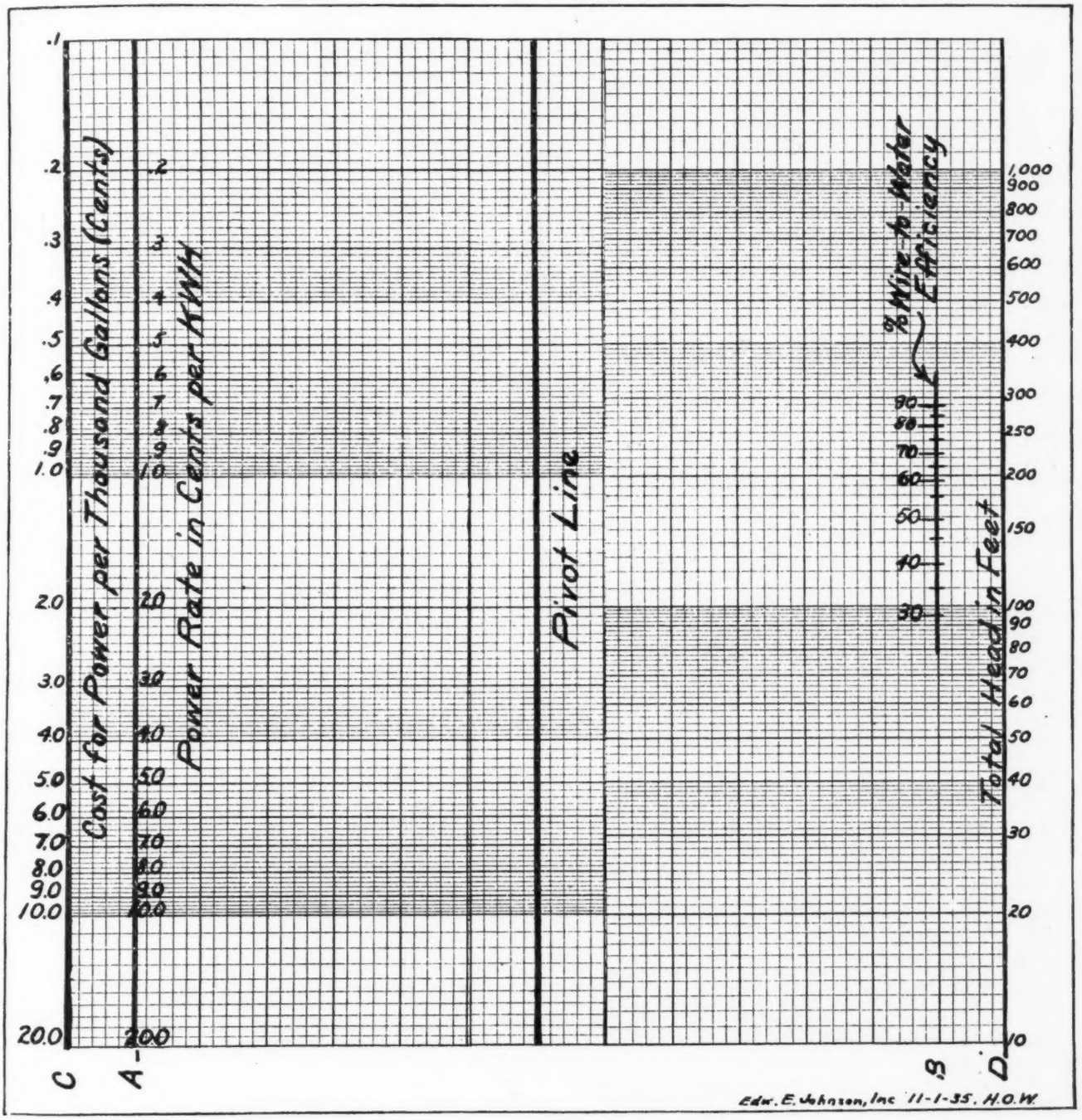
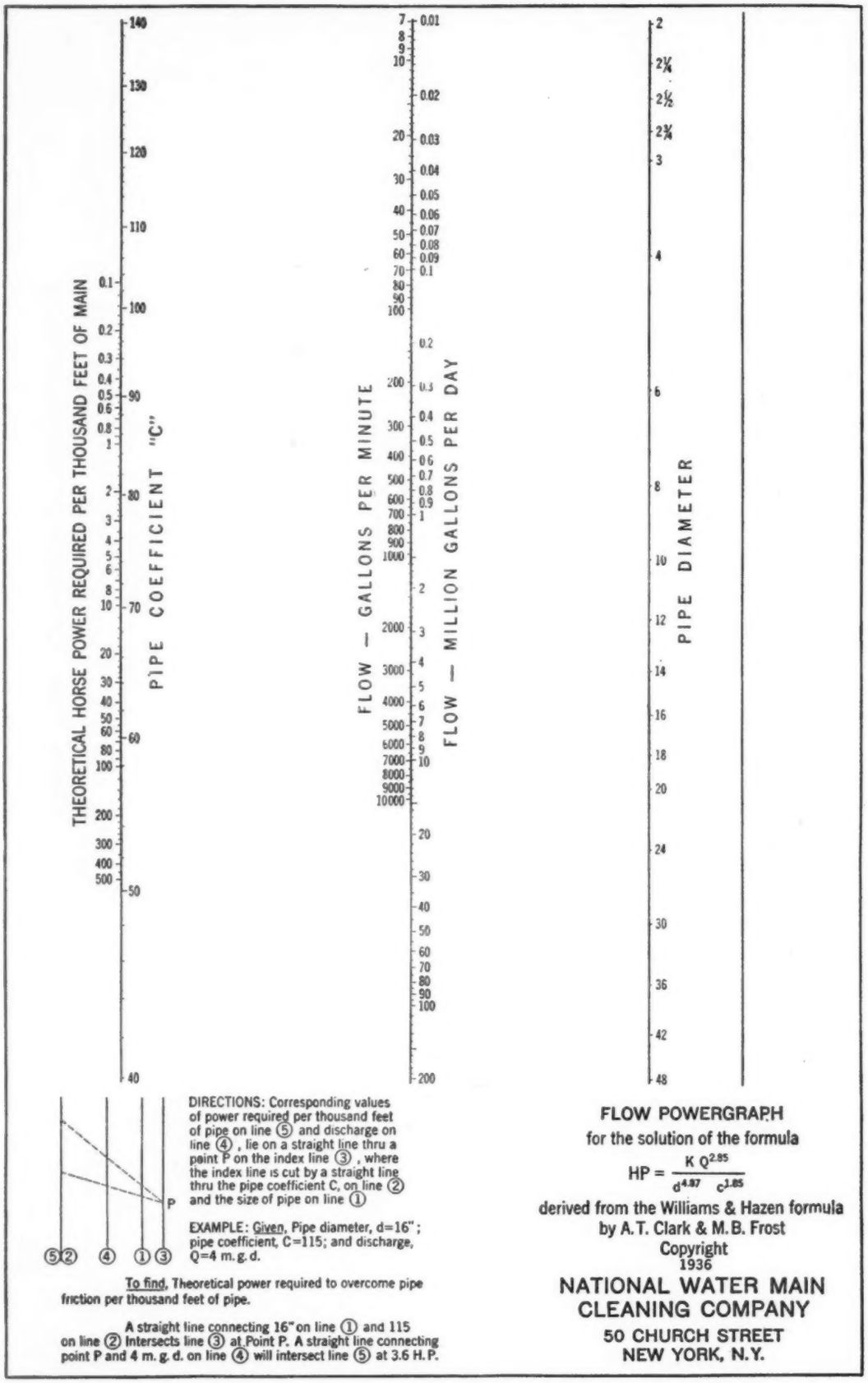


CHART FOR DETERMINATION OF PUMPING COSTS

This chart is used for determining the power cost of pumping water per thousand gallons when the total head, wire-to-water efficiency and power rate are known. In using this chart a ruler is placed from line A (Power Rate in Cents per Kilowatt Hour) to line B (% Wire-to-Water Pump Efficiency). A pin or pencil point is placed against the edge of the ruler on the Pivot Line and the ruler is then pivoted to the proper point on line D (Total Head in Feet). The Cost for Power per Thousand Gallons can then be read directly from line C at the left of the chart. *(Courtesy Edward E. Johnson, Inc.)*



Flow Powergraph


THEORETICAL HORSE POWER REQUIRED PER THOUSAND FEET OF MAIN
PIPE COEFFICIENT "C"
FLOW — GALLONS PER MINUTE
FLOW — MILLION GALLONS PER DAY
PIPE DIAMETER
DIRECTIONS: Corresponding values of power required per thousand feet of pipe on line ⑤ and discharge on line ④, lie on a straight line thru a point P on the index line ③, where the index line is cut by a straight line thru the pipe coefficient C, on line ② and the size of pipe on line ①
EXAMPLE: Given, Pipe diameter, d=16"; pipe coefficient, C=115; and discharge, Q=4 m.g.d.
To find, Theoretical power required to overcome pipe friction per thousand feet of pipe.
A straight line connecting 16" on line ① and 115 on line ② intersects line ③ at Point P. A straight line connecting point P and 4 m. g. d. on line ④ will intersect line ⑤ at 3.6 H.P.
FLOW POWERGRAPH
for the solution of the formula
HP = K Q^2.85 / d^4.87 c^1.85
derived from the Williams & Hazen formula
by A.T. Clark & M.B. Frost
Copyright
1936
NATIONAL WATER MAIN CLEANING COMPANY
50 CHURCH STREET
NEW YORK, N.Y.

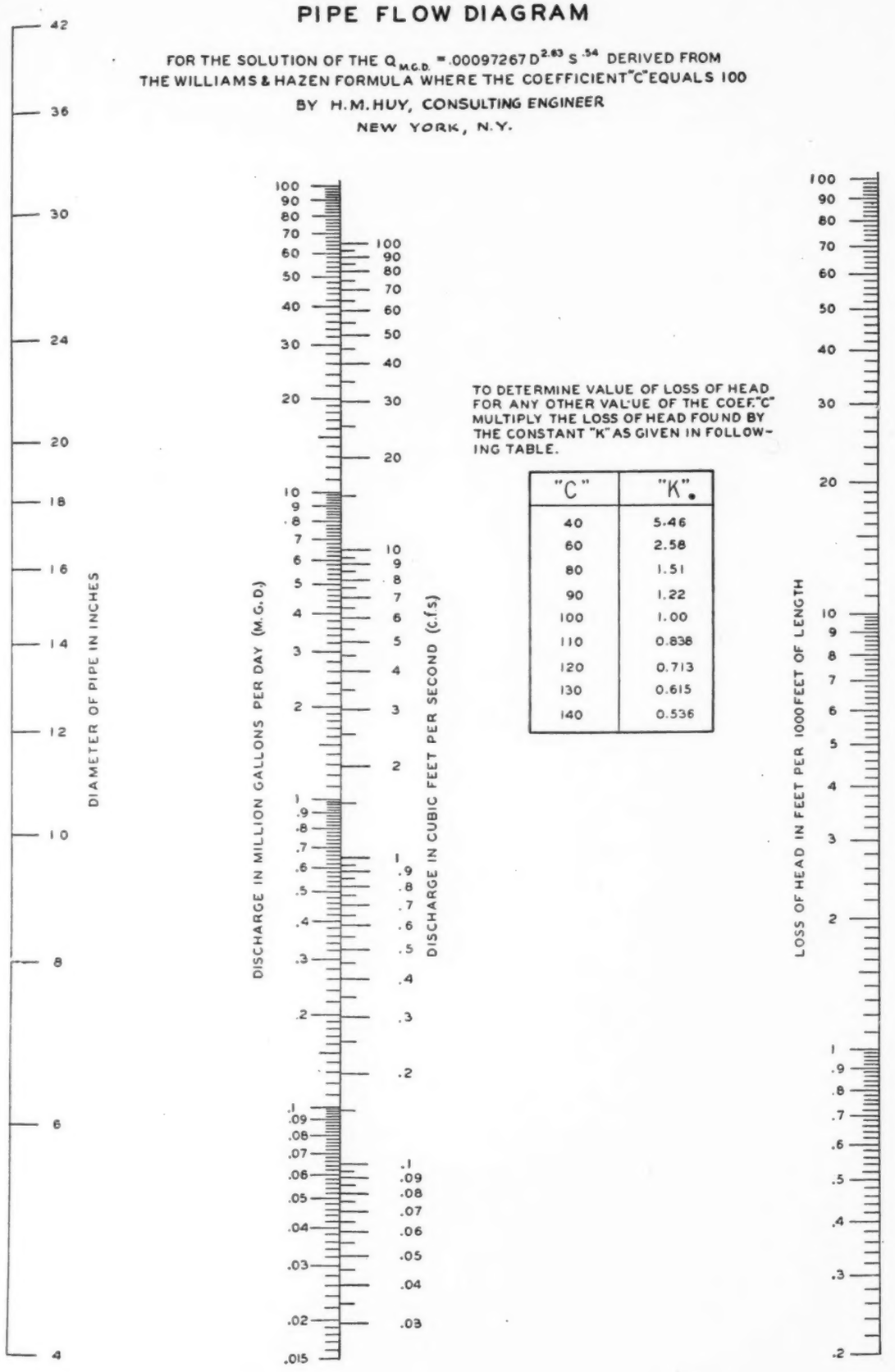
This Highly Useful Graph Was Devised by Arthur T. Clark and M. B. Frost for Simplified Determination of Power Required to Overcome Pipe Friction Under Various Conditions. Also to Determine Condition of Pipe Lines in Service.
(Copies of This Graph on Linen Are Being Distributed Gratis by National Water Main Cleaning Co., New York City.)

PIPE FLOW DIAGRAM

FOR THE SOLUTION OF THE $Q_{M.G.D.} = .00097267\,D^{2.63}\,S^{.54}$ DERIVED FROM THE WILLIAMS & HAZEN FORMULA WHERE THE COEFFICIENT "C" EQUALS 100

BY H. M. HUY, CONSULTING ENGINEER

NEW YORK, N.Y.


DIAMETER OF PIPE IN INCHES
DISCHARGE IN MILLION GALLONS PER DAY (M.G.D.)
DISCHARGE IN CUBIC FEET PER SECOND (c.f.s.)
LOSS OF HEAD IN FEET PER 1000 FEET OF LENGTH

TO DETERMINE VALUE OF LOSS OF HEAD FOR ANY OTHER VALUE OF THE COEF. "C" MULTIPLY THE LOSS OF HEAD FOUND BY THE CONSTANT "K" AS GIVEN IN FOLLOWING TABLE.

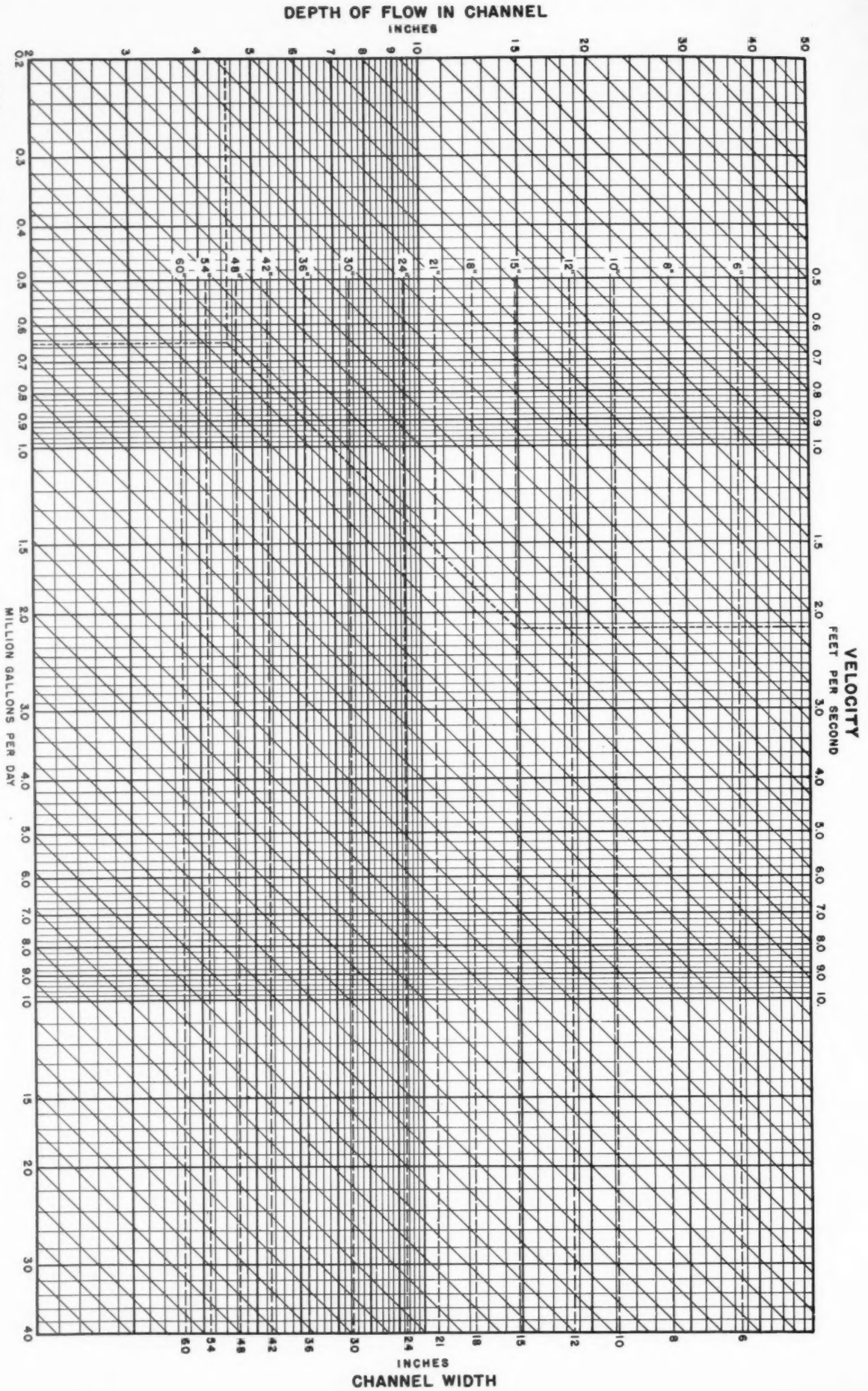
"C"	"K".
40	5.46
60	2.58
80	1.51
90	1.22
100	1.00
110	0.838
120	0.713
130	0.615
140	0.536

Directions for Application of This Diagram

(a) **FRICTION-HEAD LOSS:** A line run from pipe diameter (left vertical) through M.G.D. rates of flow (center) intersects friction vertical (right) to reveal computed friction loss per 1,000 ft. of pipe line; or pressure required per 1,000 ft., in pumping, to overcome such loss due to friction at corresponding line capacity. (If the friction coefficient, due to greater roughness or smoothness of the pipe walls, is other than the base used ["C=100"] multiply the head loss obtained by the corresponding "K" factor given for various "C" values in the "C-K" table on the chart.)

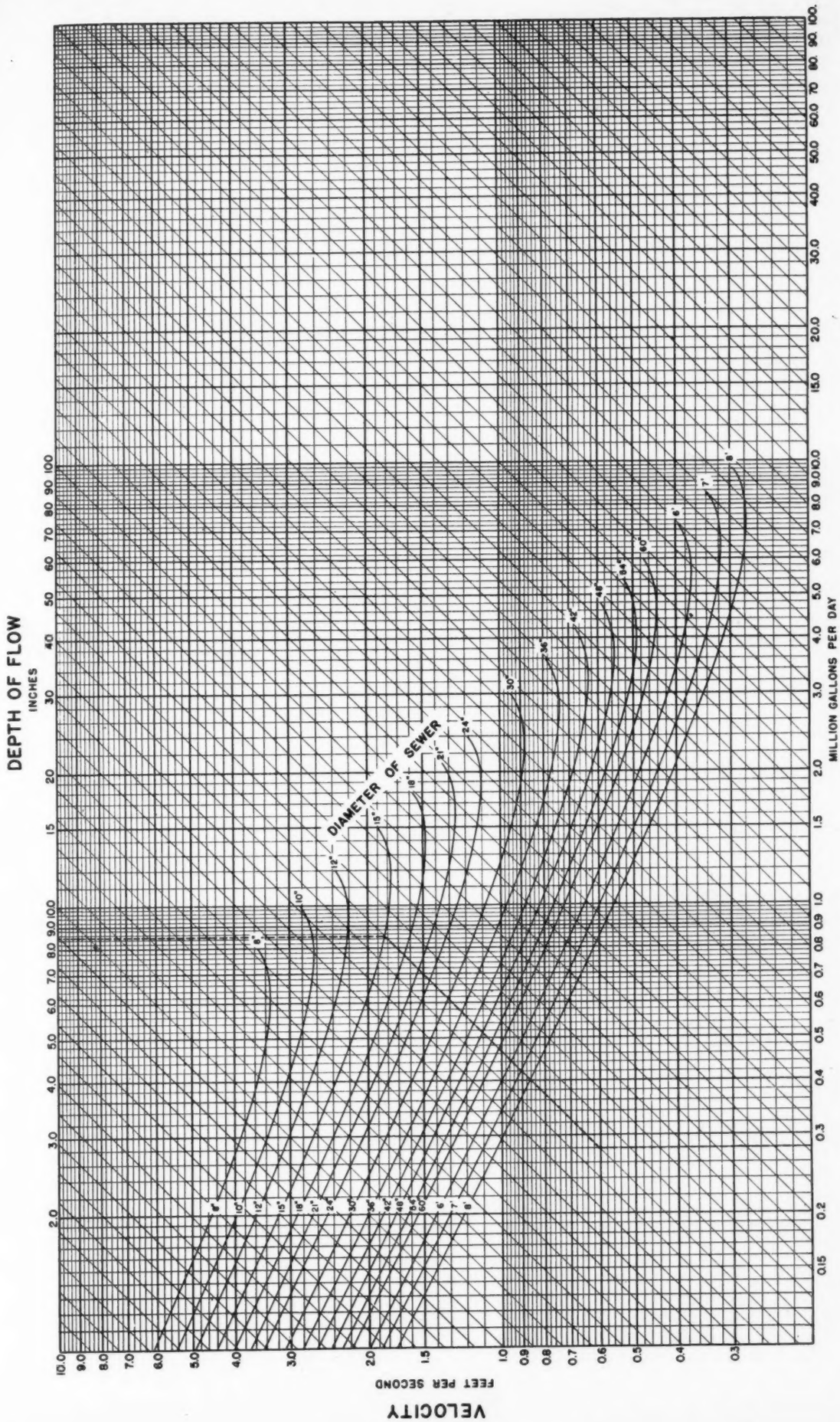
(b) **FRICTION COEFFICIENT "C":** Determine hydrant discharge rate (M.G.D.) at the end of a section of pipe line. Take simultaneous pressure readings at non-flowing hydrants on the same line several hundred feet ahead. Correct all pressure readings for difference in elevations of gages and calculated friction head loss per 1,000 ft. of intervening pipe*. From flow rates observed and known pipe diameter, follow Example (a) to obtain loss of head which would have resulted with coefficient at "C100." This figure divided into the actual (observed) loss of head reveals the "K" factor and from the useful "C-K" table the coefficient "C" can be approximated. *Accuracy depends upon use of tested pressure gages, careful flow measurements, and inducing a large loss of head between the non-flowing hydrants. For procedure in making hydrant flow tests, see article by Wilson elsewhere in this Section.)

(This diagram is reproduced through courtesy of H. M. Huy and permission of Hydraulic Development Corp. At a location earlier in this Data Section "Practical Methods of Making Flow Tests at Hydrants" are described by P. S. Wilson.)



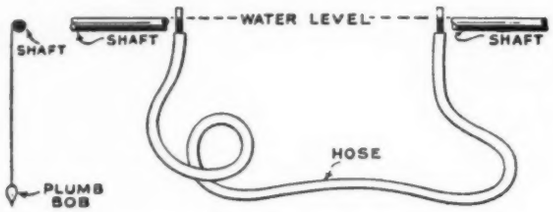
RECTANGULAR CHANNEL

This very useful graph for use in design or in determining rates of flow or velocities in existing rectangular channels is reproduced through courtesy of Chicago Pump Co.



This very useful graph for use in design or in determining velocities or rates of flow in existing pipe lines and sewers is reproduced through courtesy of Chicago Pump Co.

ACCURATE LEVELLING AND ALIGNING BY SIMPLE METHOD



The accompanying sketch shows how to do it. Slip gauge glasses into each end of an ordinary rubber hose and fill with enough water so that the level will show in each glass, as indicated.

When filling the hose with water, care must be exercised to be certain that all air is gotten out of the hose. Hold it in a U-position when filling. Do not attempt to fill it by immersing the hose in a tub of water. Also, one end of the hose must not be warmer than the other end. If the water in one end is warmer it will occupy greater volume and the level will not be true. In other words, get rid of all of the air and use water of the same temperature throughout.

The sketch also shows one of the simplest methods by which shafting can be aligned. Suspend several plumb bobs from the shaft as shown, all from the same side of the shaft. It is then possible to glance along from one end to the other and one can see whether or not the cords supporting the plumb bob are in perfect alignment. If they are not in alignment, the shafting is not straight and should be rectified. A cord stretched lengthwise near the vertical cords enables one to measure the exact amount of misalignment and assist in making the shaft straight.

EXPANSION CHART*

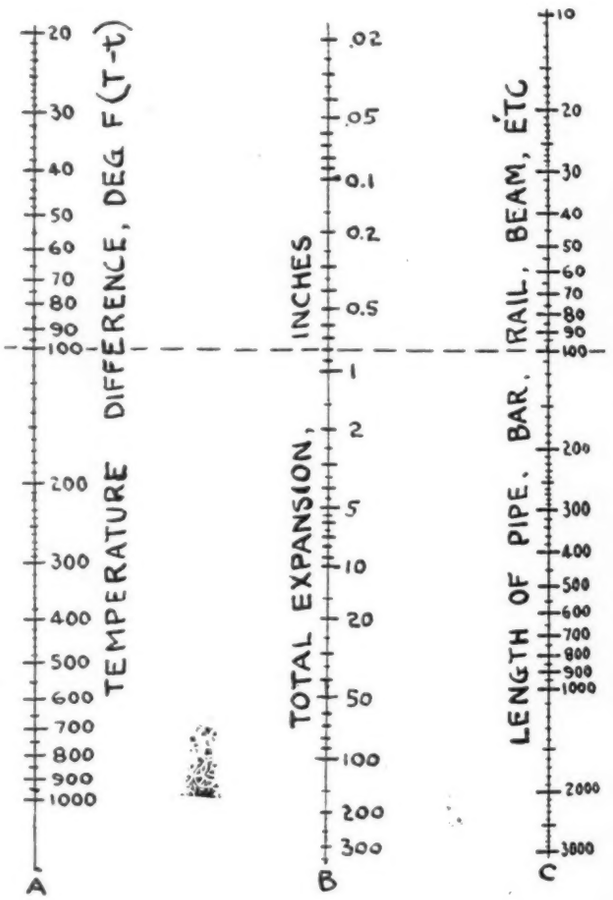
This chart is useful for determining the expansion in piping, rods, tubes, beams, shafts, columns, struts, etc., for any ordinary temperature difference. It makes "longhand figuring" unnecessary. Simply lay a straight-edge across the chart once or stretch a fine black thread across, as indicated by the dotted line, and the problem is solved.

Example: If a certain pipe line 100 ft. long is subjected to a temperature variation of 100 deg. F., what will be the total expansion in inches?

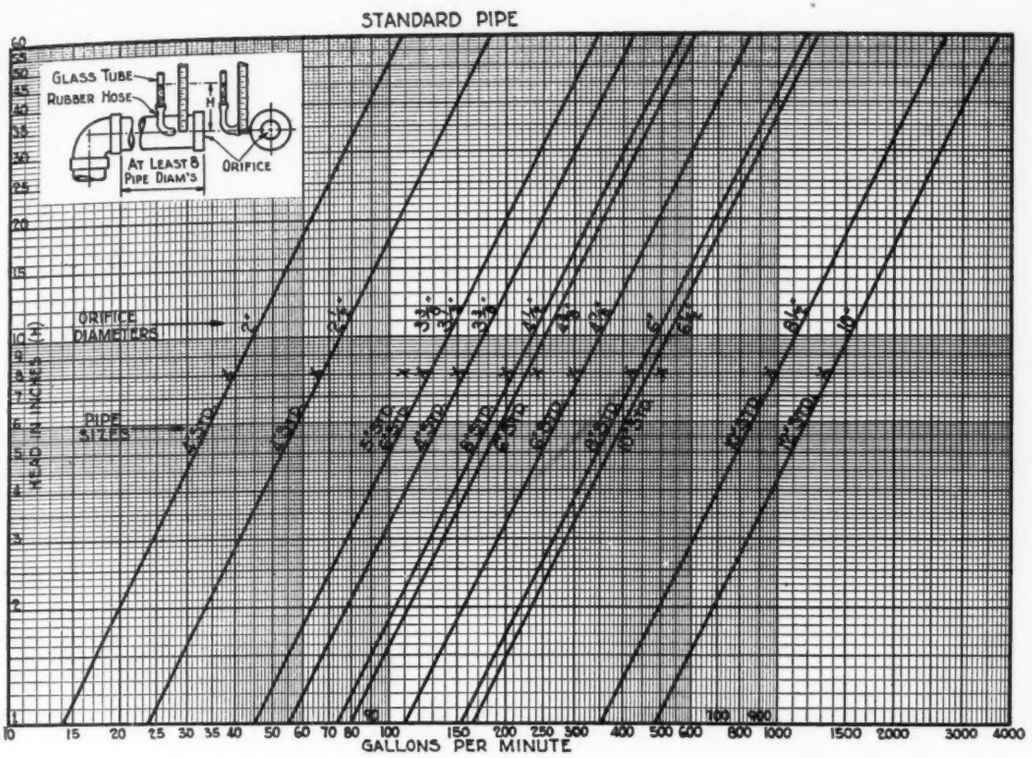
Simply connect the 100 deg. *temperature difference*, column A, with the 100 ft. length, column C. The intersection with column B gives the answer as 0.8 in. That is all there is to it.

The chart can also be used for determining the allowable temperature difference where a definite amount of space is available for expansion and contraction. Thus if the length of the pipe is 100 ft. and the allowable expansion is 0.8 in. the same line would show that a temperature difference of 100 deg. F. would be the limiting amount.

*From an article by W. F. Schaphorst, M.E., Newark, N. J., in WATER WORKS & SEWERAGE, March, 1939.



FLOW MEASUREMENTS WITH THE CIRCULAR ORIFICE AT END OF PIPE



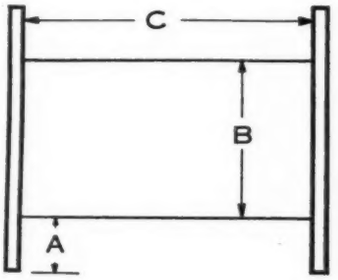
(Peerless Pump Bul.)

To obtain an accurate result in measuring the flow of water with a circular orifice the following conditions are to be maintained: Pipe must be horizontal with no elbows, obstructions or bends within 8 pipe diameters of discharge end; the orifice must be running full of water and "H" be at least one inch above top of the pipe.

Drill and tap discharge pipe on the side through center line for ⅛" pipe connection one foot back from orifice. It is very important that the ⅛" nipple does not extend inside the inner wall of the pipe and should be absolutely flush.

When the rubber hose connection and the glass tube are installed "H" may be measured from the center of the pipe with an ordinary rule.

See also "Flow Measure by Orifice Method" in Part I.)



FORMULA:— $L = (A + B) \times A \times C \times K$

L = Length of rope in feet.

A = Depth of flange in inches. In computing capacity of reels "A" is reduced 1½" to 2" to provide for a clearance.

B = Diameter of drum in inches.

C = Width of drum in inches.

K = Constant which is given below for a given size of rope.

Rope Dia.	Value of "K"	Rope Dia.	Value of "K"
1/32	266.24	7/8	.342
1/16	66.56	1	.262
3/32	29.76	1 1/8	.207
1/8	16.64	1 1/4	.167
5/32	10.76	1 3/8	.138
3/16	7.44	1 1/2	.116
1/4	4.16	1 5/8	.099
5/16	2.67	1 3/4	.085
3/8	1.86	1 7/8	.074
7/16	1.37	2	.056
1/2	1.05	2 1/8	.058
9/16	.828	2 1/4	.052
5/8	.672	2 3/8	.046
3/4	.465	2 1/2	.042

DETERMINING YARDAGE ON REELS OR DRUMS

Although the formula was designed for computing the length of cable, etc., of various diameters, which a reel or drum of given dimensions will accommodate, the method is equally valuable for determining footage remaining on a reel or drum, for inventory purposes or other reasons. In such instances the depth (A) is the depth (in inches) of rope, cable, wire, etc., remaining on the drum or reel.

Example: Assume a reel having a 5 in. core (B) and a width of 10 in. (C). The material is ¼ in. in diameter and its depth on the core is 2 in. (A).

$$(B + A) \times A \times C = X$$
$$(5 + 2) \times 2 \times 10 = 140$$

Now refer to table of factors for the "K" value for ¼ in. materials, such being 4.16 ∴ The footage is $140 \times 4.16 = 582$ ft. or, if ½ in. material $140 \times 1.05 = 147$ ft.

If it is desired to determine the length of rope, wire, rubber hose, copper tubing, packing, caulking yarn, etc., wound on a drum or reel, the accompanying formula will prove very helpful.

The sketch, with formula and factors, appeared in Wire Rope Cat. No. 20 of the Hazard Wire Rope Div. of American Chain and Cable Co. Inc.

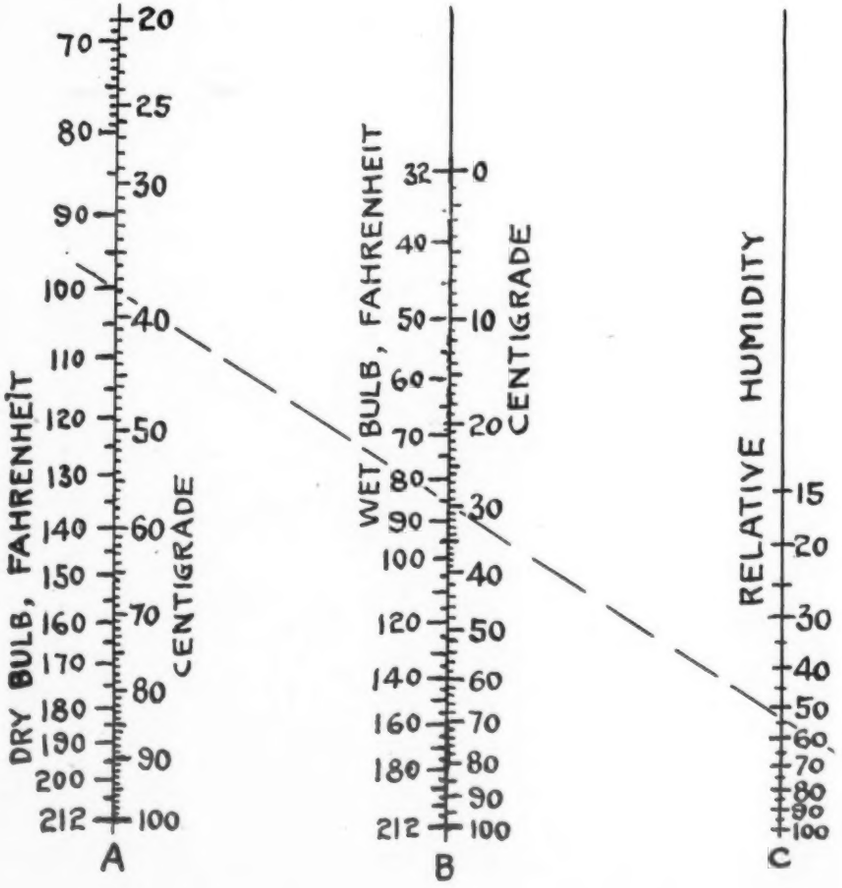
A HUMIDITY CHART*

Here is a handy chart for assisting water and sewage works operators to quickly find the relative humidity at any time. Tables and computations are unnecessary. Run a straight line through the dry bulb temperature, column A, and the wet bulb temperature, column B, and the relative humidity is instantly given at the intersection with column C. Thus if the dry bulb temperature is 100 deg. F. and the wet bulb temperature 85 deg. F., the dotted line drawn across the chart shows that the relative humidity, column C, is 54%.

The chart is based on a special formula developed by the U. S. Bureau of Standards. The formula has been tested by the Bureau for dry bulb temperatures between 20 and 100 deg. Centigrade.

The chart also has an additional reference value. The B column serves as a ready chart for converting temperatures from Fahrenheit to Centigrade and the reverse. Set up a wet and a dry bulb, and with this useful little chart watch the relative humidity of your office and also your home. It may pay you dividends.

*Contributed by W. F. Schaphorst.



AREA OF CYLINDRICAL OBJECTS*

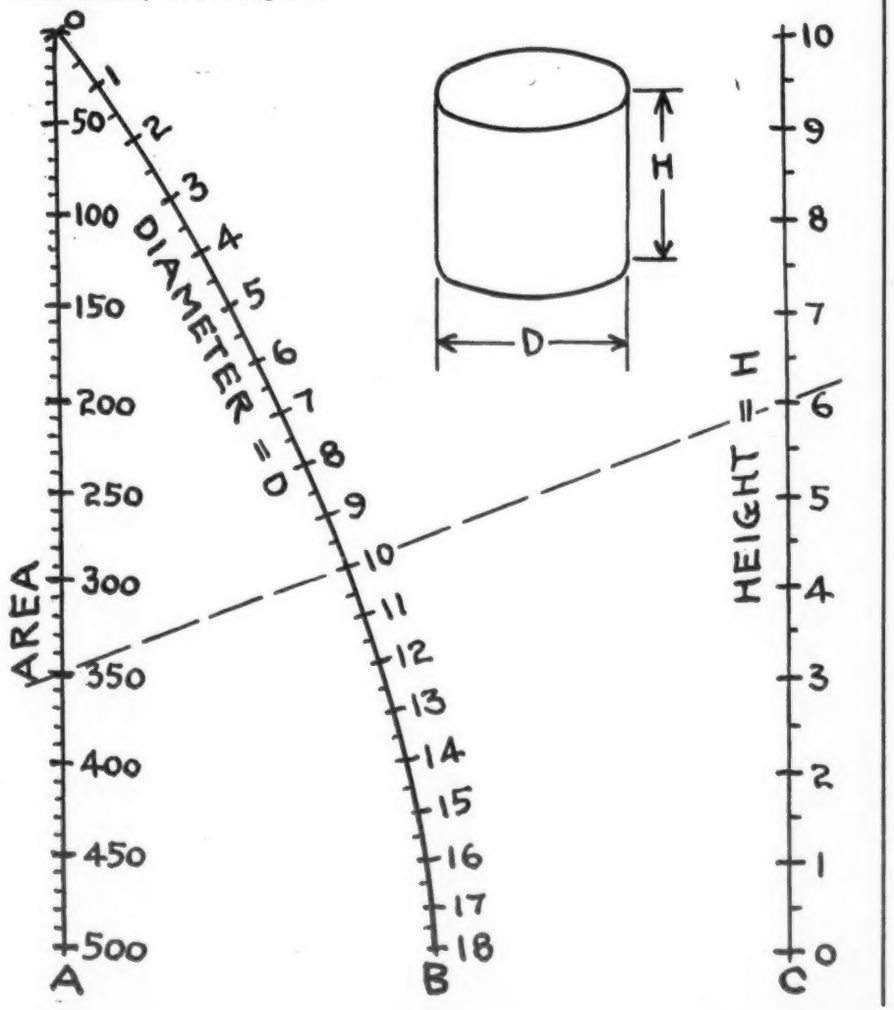
Here is a chart that instantly gives the total area of any cylinder of any ordinary height and any ordinary diameter. The chart automatically adds the two flat ends and the cylindrical surface without any "long hand" figuring whatever.

For example, if the diameter of the cylinder is 10 feet and the height 6 feet, how many square feet of metal will be required in its fabrication. Or how much surface is there to be painted, etc.

The dotted line drawn across the chart shows how easily it is done. The line passes through the 10, in the curved column B, and through the 6, in column C. The intersection with column A shows that the area is 350 sq. ft.

Of course any unit of measurement may be used. Thus if the diameter and height are in inches the area will be in square inches.

*Contributed by W. F. Schaphorst.



Thickness and Weight of Sheets and Plates

Number of Gauge	U.S. Standard Gauge Adopted by U. S. Government July 1, 1893			Birmingham or Stubs' Gauge		American or Brown & Sharpe's Gauge		Thickness of Wire: Washburn & Moen Gauge
	Thickness, Inches		Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches	Weight, Pounds, per Sq. Ft.	Thickness, Inches
0000000	1/2	.5000	20.4	.....	.....	.....	.....	.....
000000	15/32	.46875	19.125	.....	.....	.580	23.6	.....
00000	7/16	.4375	17.85	.....	.....	.5165	21.0	.....
0000	13/32	.40625	16.575	.454	18.5	.46	18.71	.3938
000	3/8	.375	15.30	.425	17.28	.409	16.71	.....
00	11/32	.343	14.025	.38	15.45	.364	14.88	.331
0	5/16	.312	12.75	.34	13.82	.324	13.26	.307
1	9/32	.281	11.475	.30	12.20	.289	11.80	.283
2	17/64	.265	10.837	.284	11.55	.257	10.51	.263
3	1/4	.25	10.2	.259	10.53	.229	9.36	.244
4	15/64	.234	9.562	.238	9.68	.204	8.34	.225
5	7/32	.218	8.925	.22	8.95	.181	7.42	.207
6	13/64	.203	8.287	.203	8.25	.162	6.61	.192
7	3/16	.187	7.65	.18	7.32	.144	5.89	.177
8	11/64	.171	7.012	.165	6.71	.128	5.24	.162
9	5/32	.156	6.375	.148	6.02	.114	4.67	.148
10	9/64	.140	5.737	.134	5.45	.101	4.16	.135
11	1/8	.125	5.1	.12	4.88	.09	3.70	.120
12	7/64	.109	4.462	.109	4.43	.08	3.30	.105
13	3/32	.093	3.825	.095	3.86	.072	2.94	.092
14	5/64	.078	3.187	.083	3.37	.064	2.62	.080
15	9/128	.070	2.868	.072	2.93	.057	2.33	.072
16	1/16	.062	2.55	.065	2.64	.05	2.07	.063
17	9/160	.056	2.295	.058	2.36	.045	1.85	.054
18	1/20	.05	2.04	.049	1.99	.04	1.64	.047
19	7/160	.043	1.785	.042	1.71	.035	1.46	.041
20	9/80	.037	1.53	.035	1.42	.032	1.31	.035
21	11/320	.034	1.402	.032	1.30	.028	1.16	.032
22	1/32	.031	1.275	.028	1.14	.025	1.03	.....
23	9/320	.028	1.147	.025	1.02	.022	.922	.....
24	1/40	.025	1.02	.022	.895	.020	.82	.....
25	7/320	.021	.892	.02	.813	.017	.73	.....
26	3/160	.018	.765	.018	.732	.015	.649	.....
27	11/640	.017	.701	.016	.651	.014	.579	.....
28	1/64	.015	.637	.014	.569	.012	.514	.....
29	9/640	.014	.573	.013	.....	.011	.461	.....
30	1/80	.012	.51	.012	.....	.01	.408	.....

STANDARD GAUGES*

Sheets, Plates and Wire

Sheet mills roll steel sheets to U. S. gauge unless otherwise ordered. Plate mills usually roll heavy plates, 3/16 and heavier, and light plate No. 8 to No. 12, to Birmingham gauge. In figuring weights of steel plates add to above the allowance for overweight, adopted by Association American Steel Manufacturers. All steel sheets in our *stock are rolled to the U. S. Standard Gauge. Brass is rolled to thickness by Brown & Sharpe's American Gauge. Copper is rolled to thickness by Stubs' or Birmingham Gauge.

* From Link-Belt Catalog.

CONTENTS OF HORIZONTAL TANKS AND PIPE

Per Foot of Length, for Various Depths

h = Depth of Liquid Inches	d = Diameter of Tank, Inches: 12 Gal.	12 Cu. Ft.	18 Gal.	18 Cu. Ft.	24 Gal.	24 Cu. Ft.	30 Gal.	30 Cu. Ft.	36 Gal.	36 Cu. Ft.
2	0.64	0.0860	0.80	0.1072	0.93	0.1244	1.05	0.1400	1.15	0.154
4	1.73	0.2317	2.18	0.2920	2.57	0.3440	2.90	0.3878	3.21	0.429
6	2.94	0.3927	3.85	0.5149	4.59	0.6140	5.23	0.6988	5.80	0.775
8	4.14	0.5537	5.67	0.7578	6.85	0.9152	7.85	1.049	8.75	1.17
10	5.23	0.6994	7.55	1.009	9.26	1.238	10.72	1.432	12.0	1.60
12	5.87	0.7854	9.38	1.252	11.75	1.571	13.72	1.833	15.4	2.03
14	.....	.....	11.04	1.476	14.24	1.903	16.82	2.248	19.0	2.54
16	.....	.....	12.43	1.659	16.65	2.226	19.90	2.660	22.6	3.02
18	.....	.....	13.22	1.767	18.91	2.527	23.00	3.075	26.4	3.53
20	.....	.....	.....	.....	20.93	2.797	26.00	3.476	29.6	3.95
22	.....	.....	.....	.....	22.57	3.017	28.85	3.859	33.4	4.46
24	.....	.....	.....	.....	23.50	3.141o	31.49	4.209	37.4	5.00
26	.....	.....	.....	.....	.....	.....	33.82	4.521	40.4	5.40
28	.....	.....	.....	.....	.....	.....	35.67	4.768	43.7	5.84
30	.....	.....	.....	.....	.....	.....	36.72	4.908	46.6	6.23
32	.....	.....	.....	.....	.....	.....	.....	.....	49.1	6.55
34	.....	.....	.....	.....	.....	.....	.....	.....	51.2	6.85
36	.....	.....	.....	.....	.....	.....	.....	.....	52.9	7.07

(Reprinted with permission from the Piping Handbook, by Walker and Crocker. Published by McGraw-Hill Book Company.)

Formulas for determination of approximate capacity of horizontal cylindrical tanks for any depth. Given:—diameter of tank d and height of segment h.

To find area of segment.

when h=0 to $\frac{1}{4}d$; area = $h\sqrt{1.766\,dh - h^2}$

when h=$\frac{1}{4}d$ to $\frac{1}{2}d$; area = $h\sqrt{0.017d^2 + 1.7\,dh - h^2}$

1 cu. ft. = 7.4805 U. S. gal.

GALLONS IN WATER SUPPLY PIPE*

Water supply men often want to know the volume of a given length of pipe in gallons. This writer does not know of any table that gives such values and where volumes are to be found they are usually given in cubic feet. Besides, the range of a table is seldom great enough to cover all desired conditions.

This chart takes care of all standard pipe sizes from ⅛ inch to 15 inches on scale A, and any length of pipe line from 0.1 foot to 800,000 feet on scale B. Scale C shows volumes from 1 to 1,000 gallons.

In using the chart simply run a straight line through the pipe size (column A) and the length of pipe line (column B) and the intersection with column C immediately gives the total number of gallons in the pipe or pipe line.

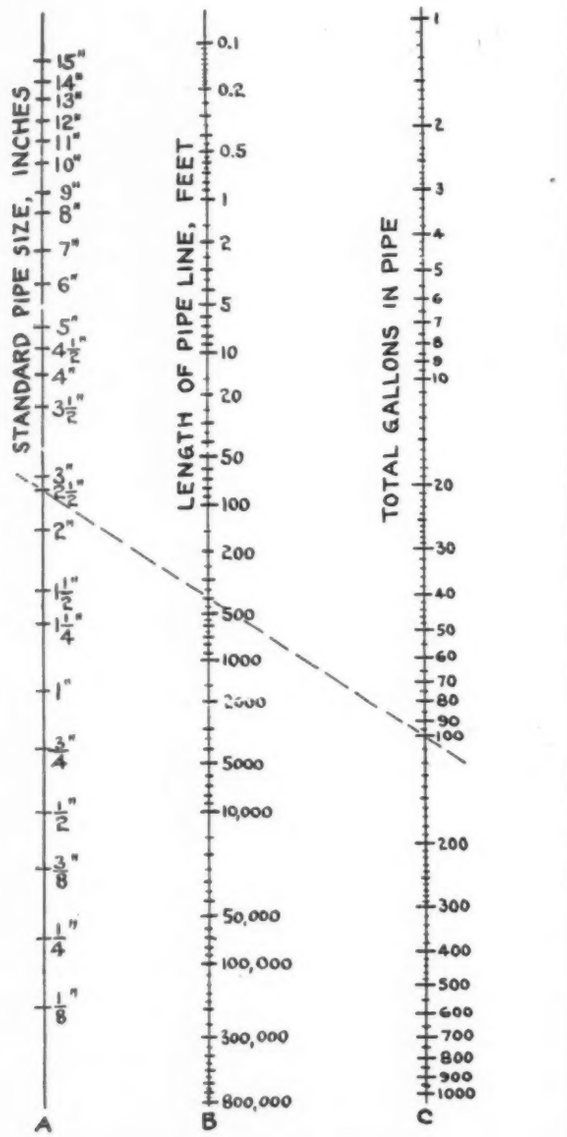
Thus the dotted line drawn across this chart shows that if the pipe size is 2½ inches (column A) and the length of line is 400 feet (column B) the volume of the pipe (column C), is 100 gallons.

For a length of pipe which is found to hold more than 1,000 gals. the volume is readily found for 1/10th or 1/100th of the length and the C scale reading multiplied accordingly.

Or, if it is desired to know the length of pipe line required to hold a given number of gallons, or the size of the pipe necessary to hold a given number of gallons within certain limitations of length, the chart may be conveniently applied. In other words, knowing two factors in any two of the three columns, the unknown in the third column is quickly found.

Here is another "trick": To determine the volume of a ½-inch pipe one foot long, the easiest way is to run a line through the ½-inch, column A, and the 10.000 in column B. The intersection with column C says 160 gallons, but that, of course, is for a pipe line 10,000 ft. long. By merely pointing off four places to the left we have 0.016 gal, as the volume of a ½-inch pipe one foot long.

* Contributed by W. F. Schaphorst (M.E.), Newark, N. J.



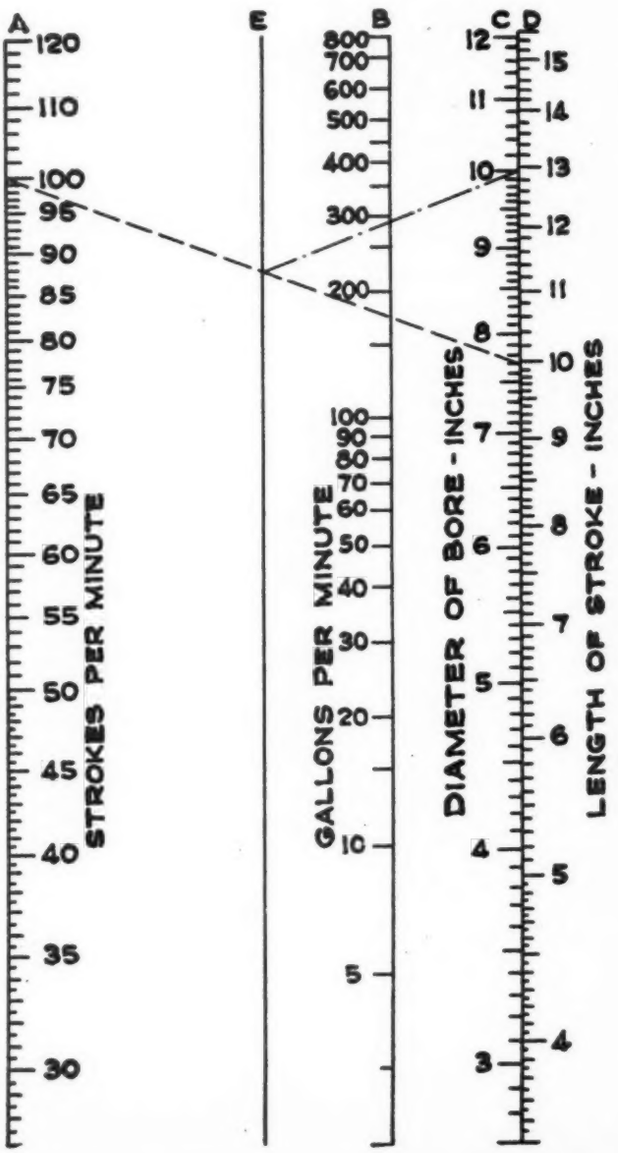
CAPACITY OF RECIPROCATING PUMPS

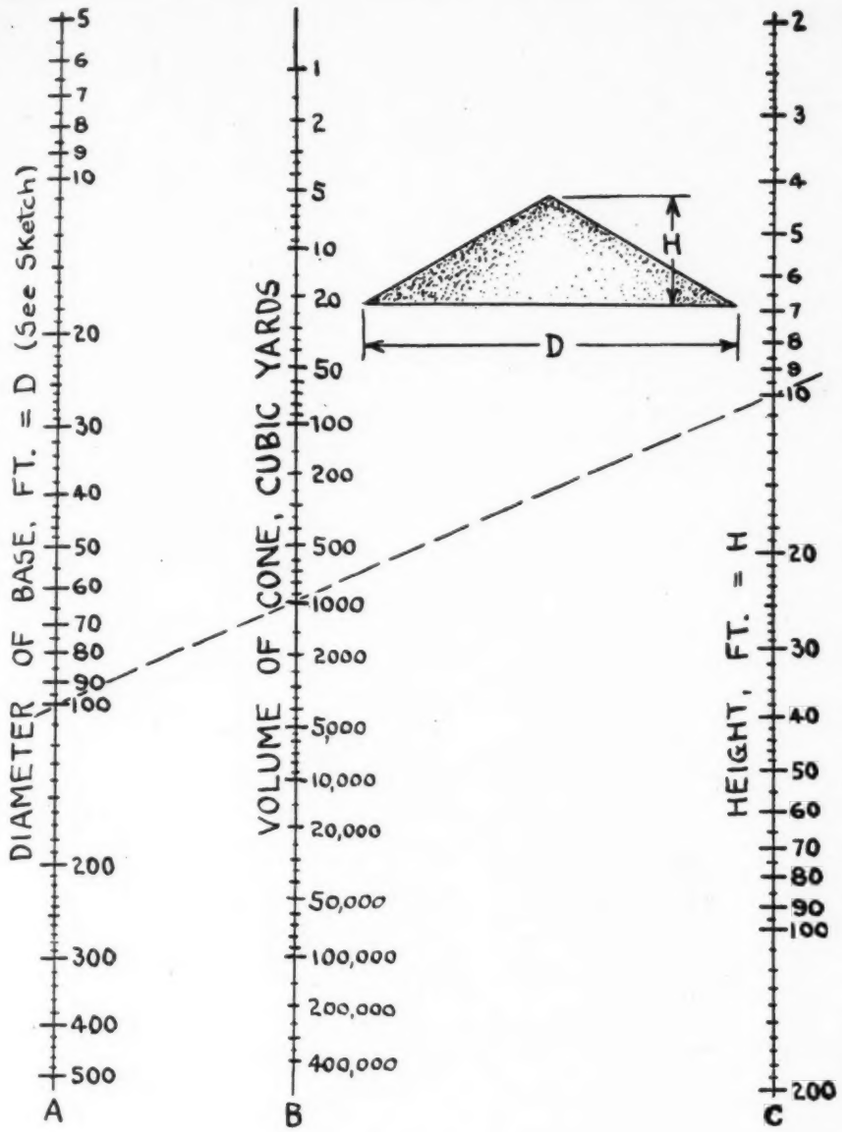
This nomograph shows the capacity of a reciprocating pump operating without slip where the size and number of strokes is known.

Example:

A pump of 10-in. bore, 10-in. stroke running 100 strokes per minute: Locating 100 on line "A" and 10-in. on line "D" we draw a line between them; then locating the intersection of this line with line "E" and locating 10-in. on line "C" we draw a connecting line. Where this line crosses "B" we have the delivery, or 290 G.P.M., of the reciprocating pump.

(From "Data Handbook" of Economy Pumps, Inc.)





CONTENTS OF CONICAL PILES*

Frequently it becomes desirable or necessary to estimate yardage in a pile of dirt, sand, stone, gravel, coal, etc.

Without any figuring whatever the accompanying chart quickly gives the number of cubic yards in any conical pile.

For example, how many cubic yards in a conical pile whose based diameter is 100 ft. and whose height is 10 ft.?

The dotted line drawn across the chart shows how it is done. Run the line through the 100 ft. diameter, column A, and the 10 ft. height, Column C, and the intersection with column B gives the answer as a little less than 1000 cubic yards.

The range of the chart takes care of all diameters from 5 to 500 ft. and all heights from 2 to 200 ft. However, in the event that diameters or heights should be greater or less the same chart is still applicable. Thus if the diameter should be 1000 ft. instead of 100 ft. and if the height should be 100 ft. instead of 10 ft., the same dotted line would solve the problem excepting that the answer would be 1,000,000 cubic yards instead of 1000 cubic yards. In that case the rule is this: For every cipher added to column A, add two ciphers to the answer in column B, and for every cipher added to column C, add one cipher to the answer in column B. This means that when the problem is 1000 ft. diameter and 100 ft. height, three ciphers must be added to the result in column B.

*Contributed by W. F. Schaphorst, M.E.

LAND MEASURE

A Quarter Section of 160 Acres Divided to Show Relationship of Rods, Chains and Feet

A rod is 16½ feet.

A chain is 66 feet or 4 rods.

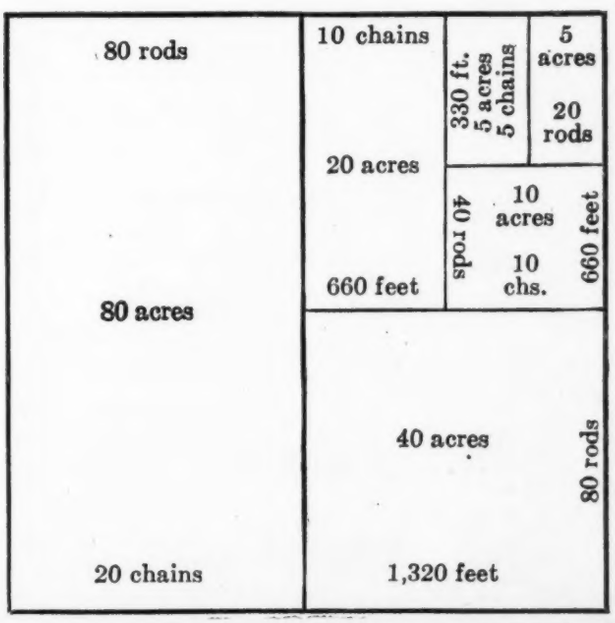
A mile is 320 rods, 80 chains or 5,280 ft.

A square rod is 272¼ square feet.

An acre contains 43,560 square feet.

An acre contains 160 square rods.

An acre is about 208¾ feet square.



HYDRAULIC POWER-LIFT CHART*

This chart will be found convenient for solving a multitude of cylinder problems in connection with water plant machinery. It eliminates all of the longhand figuring that is usually necessary in computing the total pressure on a piston, the capacity of a pressure hoist, the pressure needed to achieve a given lift, and so on.

Thus, for instance, if you have a cylinder that is 6 in. in diameter and a pressure of 100 pounds per square inch, the dotted line drawn across this chart connecting the 6 in column A with the 100 in column C shows in column B that the cylinder will have a lifting capacity of a trifle over 2500 pounds. Thus, simply connect the known diameter in column A with the known pressure in column C and the intersection through column B gives the lift capacity in pounds.

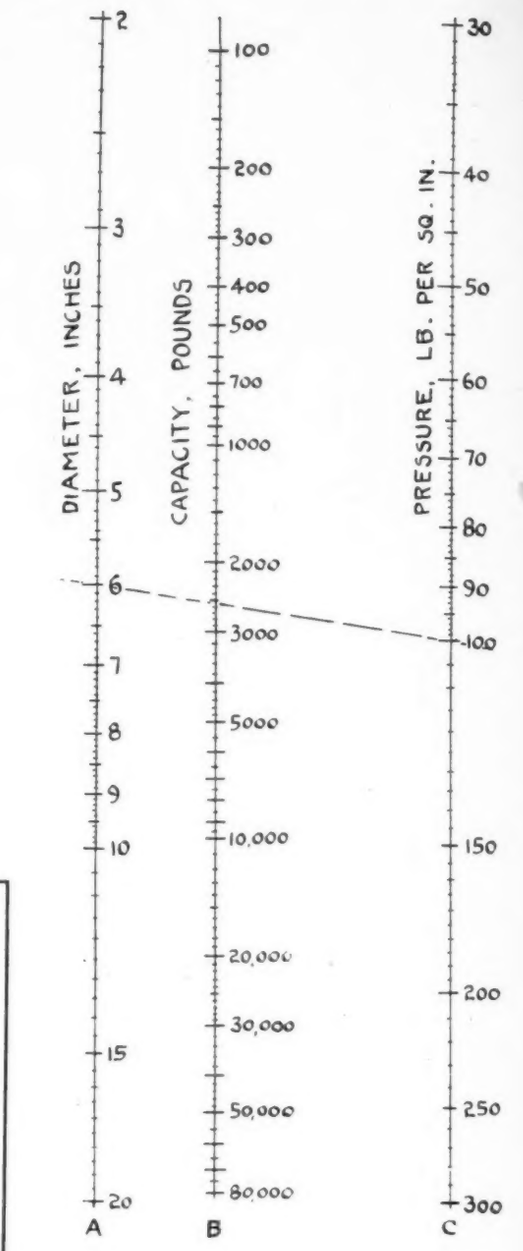
If, on the other hand, it is desired to choose a cylinder to provide a life capacity of 2500 pounds, knowing the pressure to be 100 pounds per square inch, the same dotted line gives a diameter of 6 in. Or, if the available head is only 50 pounds a line from 50 (Col. C) through the 2500 pounds (Col. B) reveals that a piston of 8.5 inches is required.

Run a straight line through any two known factors and the intersection with the third line gives the answer. Thus, if you want a capacity of 2500 pounds and you have a cylinder whose diameter is only 6 in. a pressure of 100 pounds per square inch will be needed to produce the desired capacity. If you have an 8-in. cylinder then the pressure need be but 55 pounds—line from 8 in Col. A through 2500 in Col. B.

As will be noted, the chart has a great enough range to take care of any ordinary requirements, the diameters ranging from 2 to 20 in. and the pressures from 30 to 300 pounds per square inch. The lift capacities (Column B) range all the way from 100 pounds to 80,000 pounds, or 40 tons.

The graph is applicable to all of the fluids that are used in work of this nature—air, water, oil, etc.

*Contributed by W. F. Schaphorst.



WHERE THE WATER DOLLAR GOES

Here is an interesting and enlightening chart taken from the 22nd Annual Report of the Water Department, Springfield, Ill.

It is based on a survey made by H. V. Pedersen, Water Supt., at Marshalltown, Iowa, to determine what percentage of water in the average consumer's home goes for various uses.

The Springfield folks have taken these percentages and made them more real to the customer, by showing him that out of every dollar paid for water used it only cost him 1 cent to wash his car, only 4 cents for laundry work at home, 3 cents for sprinkling in summer.

CALCULATION OF AREAS, VOLUMES, SURFACES REDUCED TO SIMPLE TERMS

Mensuration is arithmetic applied to geometry in determining the length of lines, the area of surfaces, and the volume of solids or bodies.

Definitions of geometrical terms, figures and principles. A point (.) has position only. A line (———) has length only. Area has length and breadth. A solid has length, breadth and thickness. Parallel means extended in the same direction, and equidistant at all points. Horizontal means parallel with water level; vertical or perpendicular, parallel with plumb line; diagonal, obliquely across a polygon. (Fig. 4.) Equilateral means, having equal sides. Quadrilateral, having four sides. An angle (Fig. 1) is formed by two straight lines diverging from a common point called the vertex. A right angle (Fig. 2) is formed by two straight lines meeting perpendicularly. An oblique angle is either (acute—Fig. 1) smaller, or (obtuse—Fig. 3) greater than a right angle.

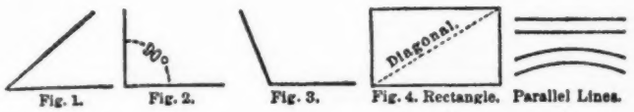


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Rectangle. Parallel Lines.

A plane or plane figure has area or surface only—perfectly even.

A polygon is a plane figure having three or more equal sides.

A triangle is a plane figure bounded by three straight lines.

An equilateral triangle (Fig. 6) has all of its (3) sides equal. An isosceles triangle (Fig. 7) has two of its sides equal. A scalene triangle (Fig. 5) has none of its sides equal. The base is the side on which a geometrical figure is supposed to stand. The least distance between the base and the opposite angle dotted line (Fig. 7) or between parallel lines (Fig. 8) is called the perpendicular or altitude.

To find the area of a triangle. Rule—Multiply base by the altitude and take half of the product. Or, when the three sides are given. From half of the sum of the three sides, subtract each side separately; then multiply the half sum and the three remainders together and extract the square root. Find sq. ft. in a triangle, base 8 ft., altitude 9 ft.

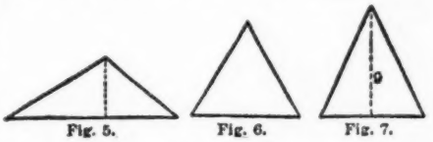


Fig. 5. Fig. 6. Fig. 7.

Answer—$(8 \times 9) \div 2 = 36$.

A parallelogram is a plane figure, bounded by four straight lines, whose opposite sides are equal, as a rectangle, a square, and a rhomboid.

A rectangle is a right angled parallelogram. A square is an equilateral rectangle. A rhomboid is an oblique angled parallelogram.

To find the area of a parallelogram. Rule—Multiply the length by the width.

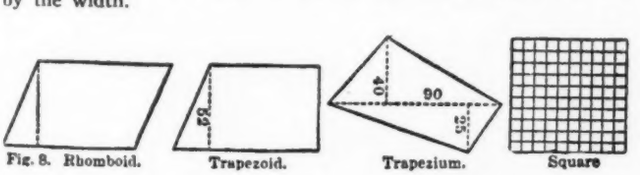


Fig. 8. Rhomboid. Trapezoid. Trapezium. Square

How many sq. ft. in a rectangle 17 by 24?

Answer—$17 \times 24 = 408$ sq. ft.

In a (square) floor 10 by 10?

Answer—$10 \times 10 = 100$ sq. ft.

Note—Dividing the area of a rectangle by one side gives the other side—if unknown.

A *trapezoid* is a quadrilateral having two of its sides parallel. To find its area. Rule—Multiply its average length by the width.

How many sq. yd. in a garden whose parallel sides are 60 and 80 yd., and width 52 yd.?

Answer—$(60 + 80 \div 2) = 70$; then, $70 \times 52 = 3{,}640$ sq. yd.

A *trapezoid* is a quadrilateral having two of its sides parallel.

To find its area. Rule—Form two triangles by a diagonal line, then multiply diagonal by sum of perpendiculars and take half of product.

Find sq. rods in field shaped like a trapezium, whose diagonal is 90 rods, and perpendiculars (25 and 40) 65 rd.

Answer—$90 \times 65 = 5850 \div 2 = 2925$ rd.

A *rightangled triangle* has one right angle. Its longest side is called hypotenuse, and the other two, base and perpendicular or altitude. To find its area. Rule—Multiply the base by the perpendicular and take half of the product.

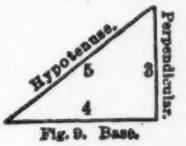


Fig. 9. Base.

How many square rods in a triangular field whose base is 70 rods and the perpendicular, 48 rods?

Answer — $(70 \times 48) \div 2 = 1680$ square rods.

Properties of the rightangled triangle. The square of the hypotenuse equals the sum of the squares of the base and the perpendicular. From this principle—illustrated by Fig. 10—we derive the following rules.

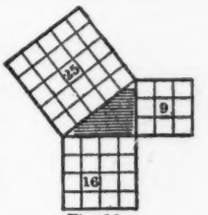


Fig. 10.

To find the hypotenuse. Rule—Add the square of the base and the square of the perpendicular, and of the sum extract square root.

A and B start from the same point, A going 4 miles due west and B, 3 miles due north; how far apart are they then?

$4^2 = 16$
$3^2 = 9$
$\sqrt{25} = 5$

Answer—5 miles.

The square of 4 (base)$=16$; of 3 (perpendicular)$=9$; the square root of their sum $(25)=5$, the hypotenuse.

To find the base or perpendicular. Rule—From the square of the hypotenuse, subtract the square of the other given side, and of their difference extract the square root.

Find the perpendicular of a triangular field whose hypotenuse is 75 rods, base 60 rods. Answer—45 rods.

$75^2 = 5625$
$60^2 = 3600$
$\sqrt{2025} = 45$

Note—To find the difference between the squares of two numbers, simply multiply their sum by their difference.

To find the side of a square equal in area to any given quantity. Rule—Extract the square root of the given quantity.

Thus, the dimensions of a square field containing 4000 square rods must be $(\sqrt{4000} = 63.246)$ 63¼ rods, nearly. Proof: $63\frac{1}{4}^2 = 4000 +$

To find the diagonal of a square. Rule—Multiply one side of the square by 10, diminish the product by 1% of itself and divide remainder by 7.

What is the diagonal of a field 35 rods square?

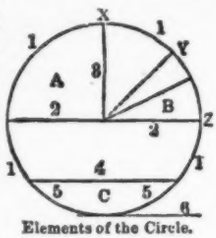
This is a simple way of finding the hypotenuse of a triangle whose base and perpendiculars are equal.

$35 \times 10 = 350.$
1% of $350 = 3.5$
$7)346.5$
Ans. (rd.) 49.5

The Circle

A circle is a plane figure bounded by a curved line, (1, 1, 1, 1) called circumference, every point of which is equally distant from

the center. The diameter is a straight line (2, 2) across a circle, through its center. The radius is a straight line (3) from the center to the circumference. An arc is any part of the circumference (5, 5). A chord, a straight line (4) joining ends of an arc. A tangent (6) touches circum. without cutting it. A segment is space (C) enclosed by arc and chord. A sector, space (B) enclosed by two radii and arc. A quadrant (A) is 90° or the fourth part of circle. A circle is divided into 360°; from X to Y is 45°; from X to Z, 90°. A sextant is one-sixth of a circle.



Elements of the Circle.

To find the *circumference* of a circle, the diameter being given. Rule—Multiply the diameter by 3 1/7; for greater accuracy, by 3.1416.

Find circumference of bicycle wheel; diam. 28 in.

Answer—28 × 3 1/7 = 88 in.

To find the *diameter* of a circle, the circumference being given. Rule—Divide the circumference by 3 1/7, or multiply it by .3183.

Circumference of a tree 144½ in., find diam.

Answer—144.5 × 3183 = 46 in.

To find the *area* of a circle. Rule—Multiply the square of the diameter by .7854; or the square of the radius by 3.1416; or the square of the circumference by .07958.

Find the area of a piston 20 in. in diam.

Answer—20^2 × .7854 = 314.16 sq. in.

Over how many sq. ft. can a cow graze, staked to a rope 50 ft. long? Here, 50 feet is the radius.

Answer—50^2 × 3.1416 = 7854 sq. ft.

To find the *radius* of a circle, the area being given. Rule—Multiply the area by .3183 and extract the square root of the product.

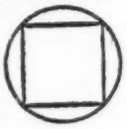
Find length of halter, tied to stake, that will enable horse to graze on 1 acre.

Answer—Square feet in acre, 43560 × .3183 = 13865; √13865 = 117¾ ft. long.

Note—The circumference of a circle is 3.1416 times greater than the diameter. The number 3.1416 (called Pi); its reciprocal, .3183; its 4th part .7854, its 6th part .5236, and others, should be committed to memory as they are indispensable factors in computing the areas and volumes of circular figures and bodies.

To find the *area of a sector* of a circle. Rule—Take such a part of the circle as the degrees in the given arc, are part of 360. Thus, a sector whose arc is 40°, contains 40/360 or 1/9 of the area of the circle.

To find the side of the greatest square that can be inscribed in a given circle. Rule—Multiply the diameter of the circle by .707; or the circumference by .225.



The diameter of a log is 24 inches; how large a sill can be cut from it?

24 × .707 = 17 in. square, nearly.

To inscribe the greatest equilateral triangle. Rule—Multiply the diameter of the circle by .886.

Side of greatest inscribed hexagon equals the radius of a circle.

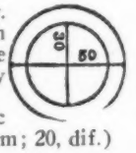
To find the diameter of a circle that will inscribe a given square. Rule—Multiply the side of the desired square by 1.414.

What must be diam. of a log to cut a sill 12 in. sq.?

Answer—12 × 1.414 = 17 in.

The area of the greatest square inscribed in a given circle is exactly ½ of the area of the least square circumscribed about the same circle—or the square of its diameter.

To find the area between the two *concentric circles*. Rule—Take the difference between the area of each circle. A simpler way is to multiply the sum of the two diameters by their difference, and the product by .7854.



Find the area included between two concentric circles whose diameters are 30 and 50 inches. (80, sum; 20, dif.)

Answer—20 × 80 = 1600 × .7854 = 1256.64 sq. in.

To find the diameter of a circle whose area is equal to the area of a given square. Rule—Multiply one side of the given square by 1.1284.

To find the side of a square whose area is equal to the area of a given circle. Rule—Multiply the diameter of the given circle by .8862.

To find the diameter of three greatest equal circles that can be inscribed in a given circle. Rule—Multiply the diameter of the given circle by .464.

Find the diameters of the three greatest circles that can be inscribed in a circle 50 in. in diam.

Answer—50 × .464 = 23.2 in.

An *ellipse* is a plane figure bounded by an oval curved line and has a long and a short diameter or axis.

To find its circumference. Rule—Multiply the sum of the two diameters by 3.1416, and take half of the product.

Ellipse.

Find the circumference of an ellipse whose diameters are .41 and 29 ft.

(41 + 29) = 70 × 3.1416 ÷ 2 = 110 ft. nearly.

To find the *area of an ellipse*. Rule—Multiply the product of the two diameters by .7854.

How many square ft. are there in an elliptical platform whose diameters are 60 and 40 ft.?

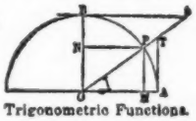
60 × 40 = 2400 × .7854 = 1885 sq. ft. nearly.

Polygons

Triangle. Square. Pentagon. Hexagon. Octagon.

To find the area of polygons, having equal sides and equal angles. Rule—Multiply the square of one of the equal sides—of a triangle, by .433; of a pentagon, by 1.7205; of hexagon, by 2.5981; of octagon, by 4.8284.

One side of an equilateral triangle is 30 inches, and of an octagon, 10 in.



Trigonometric Functions.

Find sq. in. in each.

30^2 × 433 = 389.7 in. T; 10^2 × 4.824 = 482.84 in. O.

For the benefit of those who intend to study trigonometry and surveying, this illustration is inserted here. It will be an advantage and saving of time to be already familiar with the terms and the functions of the science when beginning its study.

P M, sine.
O M, cosine.
A T, tangent.
B S, cotangent.
O T, secant.
O S, cosecant.
M A, versed sine.
B N, conversed sine.

Cubes, Cones, Pyramids, Spheres,

A *cube* is a solid body, having six equal square sides. To find its area. Rule—Multiply area of one side by 6. To find its volume. Multiply the length, the breadth and the thickness together.

Cube.

Find sq. in. in surface of a 12 in. cube.

Answer—12^2 × 6 = 864.

How many cubic in. in a cubic foot?

Answer—*12^3 = 1728.

Find cu. ft. in a cu. mile.

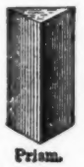
Answer—5280^3 = 147197952000.

A *parallelopiped* is a solid body whose six faces are all rectangles. To find its area. Rule—Add areas of its six sides. To find its volume. Same as the cube. How many cubic feet in a wagon bed 10½ feet long, 3 ft. wide and 1¼ ft. deep?

Parallelopiped.

Answer—10½ × 3 × 1¼ = 39⅜.

A *prism* is a solid having three or more rectangular sides, whose ends or bases are parallel plane figures. To find its area. Rule—Add areas of the sides and ends. To find its volume. Multiply the area of one end by the length.


Prism.

Find the area of a triangular prism, each of whose three sides are 10 by 25 inches.

Answers—836.6 sq. in.

10^2 × .433 × 2 = 86.6 sq. in. in area of the two ends.

10 × 25 × 3 = 750 sq. in. area of sides. 86.0 + 750 = 836.6.

How many cubic inches in above prism, 10 by 25 inches?

Answer—10^2 × .433 = 43.3 × 25 = 1082½ cu. in.

A *globe* or *sphere* is a solid body, bounded by a uniformly curved surface. To find its area. Rule—Multiply the square of diameter by 3.1416; or the square of the circumference by .3183. To find its volume. Multiply the cube of diameter by .5236.

Globe.

How many square in. in the surface; and how many cubic in. in the volume of a globe 12 in. in diameter?

Answer—904.78 cu. in. $12^2 \times 3.1416 = 452.39$ sq. in. $12^3 \times .5236 = 904.78$ cu. in.

How many cubic miles in the earth, its diameter being nearly 8000 miles?

Answer—$2000^3 \times .5236 = 268083200000$ cubic mi.

Find greatest cube inscribed in a 26 in. globe.

Answer—$26 \times .577 = 15$ in.

To find the dimensions of a cube, equivalent in volume to a given globe. Rule—Multiply the diameter of given globe by 806.

To find the diameter of a globe, equivalent in volume to a given cube. Rule—Multiply one side of the cube by 1.2407.

A *cylinder* is a round body of uniform diameter whose ends are parallel plane figures. To find its area. Rule—Multiply the circumference by the length and to the product add the areas of both ends. To find its volume. Multiply the area of one end by length.

Cylinder.

Find the area of a cylinder 30 inches in circumference and 40 inches long.

Answer—1343.24 sq. in.

$30 \times 40 = 1200$ sq. in. in convex surface.

$30^2 \times .07958 \times 2 = 143.24$ sq. in. in the two ends.

Find cubic in. in a cylinder, diameter, 20 in., length 50 in.

Answer—$20^2 \times .7854 \times 50 = 15708$ cu. in.

A *cone* is a solid, which has a circular base and tapers uniformly to a point called vertex.

A *pyramid* is a solid, resembling a cone, having three or more triangular sides.

Cone.

Pyramid.

To find the area of a *cone or pyramid*. Rule—Multiply the circumference or perimeter of the base by the slant height, and to half of the product, add the area of the base.

Find the area or surface of a cone whose circumference at base is 40 in., and slant height 50 in.

Answer—1127.33 sq. in.

$50 \times 40 \div 2 = 1000$ sq. in. in convex surface.

$40^2 \times .07958 = 127.33$ in. base.

To find the volume of a cone or pyramid. Rule—Multiply the area of the base by the height and take ⅓ of the product.

How many cubic feet in a 6 sided pyramid, 10 ft. high, whose perimeter, at base is 15 ft. or each side 2½ ft.?

Answer—54.13 cu. ft.

$2\frac{1}{2}^2 \times 2.598 = 16.24$, area of base. $10 \times 16.24 \div 3 = 54.13$.

Find cu. in. in a cone whose height is 12½ in., and diameter of base 10 in.

Answer—$10^2 \times .7854 = 78.54$ area of base. $78.54 \times 12\frac{1}{2} \div 3 = 32.25$ cu. in.

The solid contents of the cone, globe, cylinder and the cube, all of equal dimensions, are in the ratio of 1, 2, 3 and 3.82 respectively. Thus, taking 1 foot as the height and the diameter; the cone contains .2618; the globe .5236, and the cylinder .7854 of a cubic foot. The cube equals 1 cu. ft.

The *frustum of a cone or pyramid* is the part which remains after cutting off the top, parallel to the plane of the base. To find the area of a frustum. Rule—Multiply the sum of circumferences, or perimeters, by the slant height, and to half of the product, add the area of each base.

Frustums.

Find the *area of a frustum* of a cone, whose slant height is 40 in., its greater circumference, 30 in., and its smaller one, 10 in.

Answer—879.58 sq. in.

$30 + 10 \times 40 \div 2 = 800$, sides. $30^2 + 10^2 \times .07958 = 79.58$, area of bases.

To find the *volume of any frustum*. Rule—Square both ends of one side, if angular, or the diameters of both ends or bases, if round. To the two squares add the product of the given ends or diameters; ⅓ of this sum will be the area of the average base of the frustum of a square pyramid, which multiplied by .7854 equals area of average base of frustum of a cone; multiplied by .433, of a three sided frustum, by 1.7205, of a five sided fr., by 2.5981, of a six sided frustum, by 4.8284, of an eight sided frustum. For volume: multiply average area by perpendicular height.

Find the volume or capacity of a round tank whose diameter is 15 ft. at base, 12 ft. at top, and 10 ft. deep. Ans.—14.37 cu. ft.

$12^2 = 144$
$15^2 = 225$
$12 \times 15 = 180$

3)549 (183, area of av. base of F. of sq. pyr.

$183 \times .7854 = 143.73$ sq. ft., area of av. base of Fr. of cone.

$143.73 \times 10 = 1437.3$ cu. ft. $\times 7.48 = 10751$ gallons.

Find sq. ft. of lumber in a wagon tongue; large end, 4½ in. sq., small end, 2½ in., length, 9 ft. (108 in.).

Answer—$4\frac{1}{2} + 2\frac{1}{2}^2 + (4\frac{1}{2} \times 2\frac{1}{2}) \div 3 = 12\ 7/12$ sq. in., area of average base; $12\ 7/12 \times 108 = 1359$ cu. in. $\div 144 = 9\ 7/16$ sq. ft.

How many cu. ft. in a straight log, whose diameter at large end is 3 ft., small end, 2 ft., length 12 ft?

Answer—$3^2 + 2^2 + (3 \times 2) \div 3 \times .7854 = 4.974$ sq. ft., area of average base; $4.974 \times 12 = 59.69$ cu. ft.

A *spheroid* or elongated globe has a fixed and a revolving axis. To find its area. Rule—Multiply the revolving axis by the fixed axis, and that product by 3.1416. To find its volume. Rule—Multiply the square of the revolving axis by the fixed axis and that product by .5236. Find area, also the volume of spheroid; revolving axis, 20 in., fixed, 30 in.

Spheroid

$20 \times 30 \times 3.1416 = 1884.96$ sq. in. in area.

$20^2 \times 30 \times .5236 = 6283.2$ cu. in. in volume.

A *cylindrical ring* is formed by bending a cylinder. To find its area. Rule—Multiply sum of inside diam. and thickness of ring, by thickness, and the product by 9.87. To find its volume. Rule—Multiply sum of inside diam. and thickness, by square of thickness, and product by 2.467.

Ring.

Find the area, also the volume of a ring whose inner diameter is 15 inches, and whose thickness is 5 inches.

$(15 + 5) \times 5 \times 9.87 = 987$ sq. in. in area. $(15 + 5) \times 5^2 \times 2.467 = 1233.5$ cu. in vol.

To find the dimensions of *greatest cube that can be inscribed in a given globe*. Rule—Multiply the diameter of the globe by .577.

The above material has been drawn from "Ropp's Calculator"—an extremely useful and inexpensive little booklet published by C. Ropp & Sons, of Chicago.

FOR INDEX TO REFERENCE AND DATA READING PAGES, SEE PAGES 2, 3, 4 (DATA SECTION)

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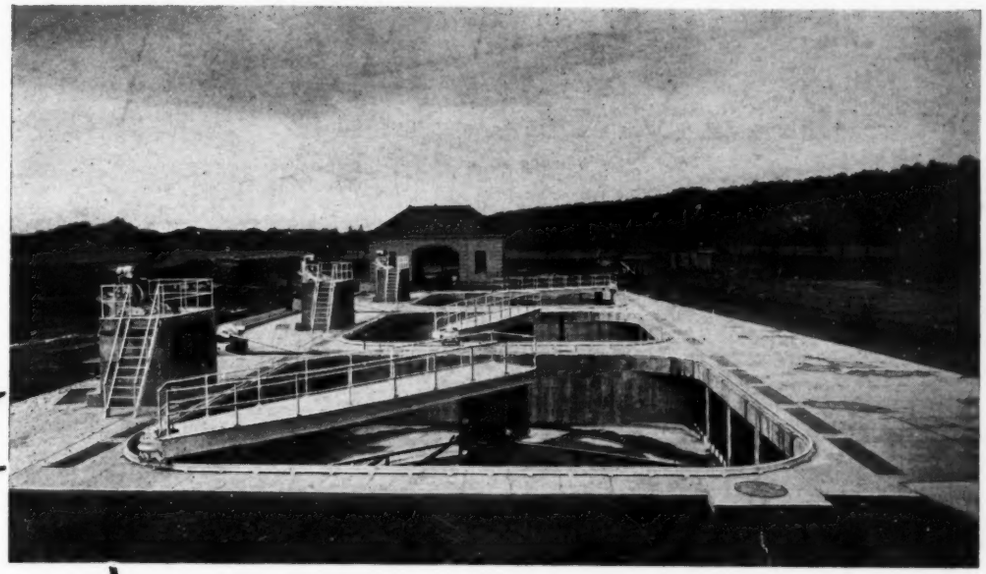
It pays TO WASH GRIT *to a* SPECIFICATION



WHAT DORR DETRITORS DO

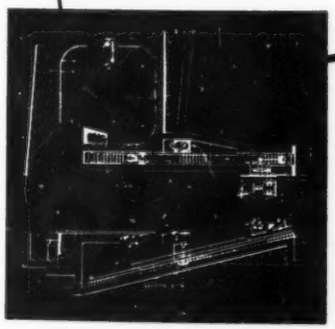
1 Remove all grit coarser than 65 mesh (or 100 mesh if you so specify).

2 Deliver a drained and washed grit containing not more than 3 per cent by weight of putrescible organics.

3 Make same removals and washings at all rates of flow—maximum, design and minimum—without adjustment.

4 Designed hydraulically to operate at minimum loss of head.

5 Structurally and mechanically designed to preclude odors, unsightliness or septic action.



Top: Three Dorr Detritors at Back River Plant, Baltimore, Md.—Capacity 300 M.G.D.

Cons. Engrs.: Whitman, Requardt & Smith, Baltimore.

Left: Typical Dorr Detritor—Plan and Elevation.

with DORR DETRITORS

Dorr Detritors are not designed on the old rule of thumb formula—"1 ft. per sec. velocity at maximum flow and 60 secs. detention." Research and field studies show that area, plus positive mechanical removal, are the governing factors, regardless of feed composition or range of flow.

Simple collection of detritus as provided in a number of units of various types and shapes is hardly enough. Complete collection of detritus *plus washing* to the specification at left can only be accomplished in a Dorr Detritor.

Proper removal of sewage grit means an end of plugged pipes and valves, worn pumps and machines and deposits in tanks, filter beds and aeration channels. Clean grit, free from putrescibles, means an easy disposal job, free from odors and unsightly conditions.

Write for a complete technical reprint on design factors in grit removal and washing.

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